DOCUMENT RESUME

ED 121 114 FL 007 632

AUTHOR	Carpenter, Patricia A.; Just, Marcel Adam
TITLE	Linguistic Control of Information Processing. Final Report.
INSTITUTION	Carnegie-Mellon Univ., Pittsburgh, Pa. Dept. of Psychology.
SPONS AGENCY	National Inst. of Education (DHEW), Washington, D.C.
PUB DATE	30 Sep 75
GRANT	NIE-G-74-0016
NOTE	164p.; For related documents, see FL 007 636-637 and EJ 112 015
EDRS PRICE	MF-$0.83 HC-$8.69 Plus Postage
DESCRIPTORS	*Cognitive Processes; Language Skills; Language Tests; Linguistic Competence; Linguistic Theory; Memory; *Negative Forms (Language); *Psycholinguistics; *Reading Comprehension; Reading Tests; Sentence Structure; Syntax; *Testing; Verbal Tests
IDENTIFIERS	*Language Processing

ABSTRACT

This research explored the fundamental processes involved in comprehending linguistic material: the duration of the process, the sequence of processes, and the sources of errors. One project examined the comprehension of affirmative and negative sentences that are read and verified with respect to a picture. A model developed to account for the sequence and duration of operations in this task also accounted for the processing of negatives in various situations, such as negatives in instructions and in test items. Another project explored how the information structure of a sentence affects comprehension. Each sentence in a paragraph generally contains some information previously given, and some new information. This project demonstrated that readers treat the two kinds of information differently. This research led to an analysis of what makes good writing: it uses the linguistic devices that minimize comprehension difficulties. A final project explored the use of eye fixations to track the processes that occur during comprehension, examining how subjects fixate a sentence and picture during various comprehension tasks. It was shown that the sequence and duration of the eye fixations can be explained in terms of the mental processes that occur during comprehension. Other papers resulting from the original research are not included here. (Author/CLK)

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ED121114

FINAL REPORT

Linguistic control of information processing

National Institute of Education Project N. I. E. G-74-0016

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September 30, 1975

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The research reported herein was performed pursuant to a grant from the National Institute of Education, U. S. Department of Health, Education and Welfare. Points of view or opinions stated do not necessarily represent official National Institute of Education position or policy.

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V	A summary of related research
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Papers resulting from research supported in part by NSF Grant G-39-6024

1. Carpenter, P. A. and Just, M. A. Linguistic influences on picture scanning. In K. A. Monty & J. W. Senders (Eds.), Eye Movements and Psychological Processes. Hillsdale, N. J., Lawrence Erlbaum Associates, 1975, in press.

2. Carpenter, P. A. and Just, M. A. Sentence comprehension: A psycholinguistic processing model of verification. Psychological Review, 1975, 82, 45-73.

3. Just, M. A. and Carpenter, P. A. Verbal comprehension in instructional situations. In D. Klahr (Ed.), Cognition and Instruction. Hillsdale, N. J.: Lawrence Erlbaum Associates, 1975, in press.

4. Just, M. A. and Carpenter, P. A. The semantics of locative information in pictures and mental images. British Journal of Psychology, 1975, in press.

5. Just, M. A. and Carpenter, P. A. Comparative studies of comprehension: An investigation of Chinese, Norwegian, and English. Memory and Cognition, 1975, 3, 465-475.

6. Carpenter, P. A. and Just, M. A. Integrative processes in comprehension. In D. LaBerge & J. Samuels (Eds.), Perception and Comprehension. Hillsdale, N. J.: Lawrence Erlbaum Associates, 1976, in press.

7. Just, M. A. and Carpenter, P. A. Eye fixations and cognitive processes. Under editorial review.

8. Christie, J. M. and Just, M. A. Remembering the location and content of sentences in a prose passage. Under editorial review.

9. Just, M. A. and Carpenter, P. A. The relation between comprehending and remembering some complex sentences. Memory and Cognition, in press.

Convention Papers Presented

1. Just, M. A. Predicting sentence memory performance from a model of the comprehension process. Paper presented at the Psychonomic Society Meetings, November, 1974, Boston, Mass.

2. Carpenter, P. A. Eye fixations during sentence comprehension. Paper presented at the Fifteenth Annual Meeting of the Psychonomic Society, November, 1974, Boston, Mass.

3. The operations underlying mental rotation. Invited paper. Midwestern Psychological Association, May 1-3, 1975, Chicago, Illinois.

In our proposed dated 4/12/71 (and revised 9/30/71), we outlined two main areas of research on fundamental skills in comprehension: the role of the processing of cognitive processes in backwardness and in terms of verbal comprehension. The other area was the role of linguistic information structures in processing sentences and discussion. The research we have planned to discussed in four manuscripts that are currently in various stages of publication. These manuscripts comprise four chapters of this final report.

The first chapter, entitled "Verbal Comprehension in Instructional Situations", considers the role of cognitive in understanding and executing instructions. Cognitive use classes because it is a very pervasive linguistic structure. However, cognitives possessed many comprehension problems that result some of the fundamental limitations in verbal comprehension. This chapter presents a theoretical model of the psychological processes involved in comprehending cognitive and effective sentences. The model accounts for the view people take to understand these sentences, the errors that they make, and the probability that they will later successfully execute the sentences. This chapter also discusses the role of comprehension skills in various setting situations. If a person cannot answer a test item or fails an instruction, it may be because the linguistic structure of the item used to convey directions. To exemplify this point, the paper analyzes actual items from various tests and shows that a significant component in successful performance is understanding the wording of the items.

The test that is very often used to answers questions decisions or predict future academic success is the reading comprehension test. In

[illegible] have a problem in given a passage in text and then a number of questions about the passage. The [illegible] research on that task suggested that two important factors that determine performance in the ability to remember where the information is located in a passage. We investigated this skill and modified the theories in Chapter 3, particularly "Theory for the Location and Retention of Information in a Prose Passage." This experiment was first steps to an analysis of the fundamental skills involved in successful performance in terms of reading comprehension.

A second suggests, entitled "Typographic Structures in Comprehension," examines the role of information processes in the retention and comprehension. This chapter examines a number of typographic devices that can be used to facilitate a reader's comprehension. Moreover, it goes on to demonstrate that these devices can used to good effects. This analysis suggests that the value for printing may be viewed from the language point of psycholinguistic processing, that is, good printing facilitates a reader's comprehension processes. All together, these first three chapters examine a number of fundamental skills that underlie linguistic competence and explores [illegible] role in various comprehension tasks.

The fourth chapter, entitled "Linguistic Control of Visual Scanning," outlines an exciting development that we are developing to model eye-[illegible] movement processes. The preliminary data in this chapter and in an accompanying paper ("Eye Fixations and Cognitive Processes") suggest that a person's eye fixations are very sensitive to the underlying mental processes. In particular, a great linguistic input can influence the way a subject moves a subsequent picture. The sequence and location of the subject's eye fixations can be analyzed by the mental processes involved

sentence said The one who loved the dog was the little boy. This latter sentence seems awkward. It is "awkward" because the reader is given an incorrect signal about what is old information. This simple linguistic device has a large effect on how long it takes to read a paragraph. A number of other linguistic devices also serve to signal to the reader what is old and what is new. These distinctions help the reader relate each sentence to previous ones.

Good writers seem to be intuitively aware of these various linguistic devices and use them to write more comprehensibly. But not everyone is born with a writer's intuitions about how to write well. Thus, there is a need for some scientific study of what makes comprehensible prose. This research is an initial step in that direction. It indicates what kinds of sentences are difficult to understand, and why. This kind of knowledge may lead to a science of writing rules that would result in easily comprehensible prose. Such rules would help eliminate difficulties in areas where efficient communication is a primary goal.

A major objective of this research is to understand the fundamental cognitive processes that occur during understanding. This knowledge may point the way towards training people in comprehension skills. It is clear that some people have difficulty understanding written or spoken directions or reprots. Research on comprehension processes may allow us to diagnose the cause of these problems. Eventually, it is hoped that this kind of research will also indicate ways of remedying comprehension problems. Thus, research on fundamental skills may indicate how we can improve the skills of the reader as well as the writer.

A final part of the current research project has explored how people visually scan various kinds of written material. This is done by record-

ing where their eye fixates while they read. For example, a person may be asked to read and solve a short, written problem. While reading, the person's eye generally fixates on various words as he progresses along. These fixations average about a quarter of a second. By comparing fixation patterns for easy and hard problems, we have been able to pinpoint the source of the difficulties that people are having. It appears that eye fixations will give a great deal of information about reading and comprehension problems. This research approach is now being explored in more detail.

CHAPTER I

Verbal Comprehension in Instructional Situations[1]

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Running head: Verbal Comprehension

Paper presented at the 10th Annual Carnegie Symposium on Cognition
Vail, Colorado, June 2-8, 1974.

To appear in Klahr, D. (Ed.), Cognition and Instruction. Potomac, Maryland: Lawrence Erlbaum Associates, 1975.

Probably the main medium for the acquisition of knowledge is verbal comprehension. The central importance of comprehension skill is recognized by our educational institutions and therefore, comprehension is often used as a criterion skill for measuring achievement and aptitude. In this paper, we will report on our investigation of one aspect of verbal comprehension, namely, the mental processes that underlie sentence comprehension. Our research takes the form of an information processing analysis, focusing on the information a person extracts from a sentence, how that information is represented internally, and what mental operations are applied to the representation. Our aim is to specify the parameters of the information processing system in simple comprehension tasks. We will validate our theoretical proposals by accounting for response latencies in a task where people decide whether a sentence is true or false. Then, we will examine verbal comprehension in a number of other tasks, showing how the same fundamental processes are common to these various situations.

This paper consists of three sections. First, we will outline an information processing model that accounts for response latencies in verifying simple and embedded affirmative and negative sentences. The negative sentences contained the explicit negative, not. Second, we will show that the same model explains how people execute simple instructions that contain implicitly negative lexical items like except, different, and forget. Third, we will examine two tasks that occur in educational tests of verbal comprehension, namely, sentence completion and reading comprehension, showing how performance in these tasks can be analyzed within the same theoretical framework.

AN INFORMATION PROCESSING MODEL OF SENTENCE VERIFICATION

The internal representation. Understanding a sentence involves internally representing the information that the sentence contains. It is likely that the format of the internal representation is propositional, a relational structure consisting of a predicate and one or more arguments. We will use the conventional notation, (PREDICATE, ARGUMENT), to denote a proposition. So part of the representation of a simple declarative sentence like The dots are red would be (RED, DOTS), meaning redness is predicated of the dots. Predications can be affirmed or negated. So, the entire representation of this affirmative sentence would be (AFF, (RED, DOTS)). A negative sentence like The dots aren't red would be represented as (NEG, (RED, DOTS)). AFF and NEG are embedding markers that denote the affirmative or negative polarity of the predication. This form of representation allows us to combine simple propositions to represent more complex sentences. For example, It is fortunate that the dots are red might be represented as (FORTUNATE, P), where P is the simple proposition (AFF, (RED, DOTS)).

The internal representation of a sentence is not necessarily linguistic in nature. The verbal symbols in these representations, e.g., DOTS, are used to denote more abstract entities. In fact, research on sentence-picture verification suggests that there may be a level of representation that is neither linguistic nor pictorial in nature but can represent information from either domain (Chase & Clark, 1972; Clark & Chase, 1972). For example, a picture of red dots may be represented (RED, DOTS). We assume that pictures are generally represented affirmatively, but by convention, we have deleted the affirmative polarity marker. The presence or absence of this marker in the picture representation has no consequence for any of our proposals, so long as it is assumed that the absence of a marker denotes affirmative polarity.

The detailed form of the representation of various kinds of sentences has

not yet been empirically verified. For example, the research on the linguistic factors that determine the psychological predicate-argument structure has only begun (cf. Halliday, 1967; Kintsch, 1972). Moreover, there are cases where various representations are formally equivalent and the selection of one particular form is really arbitrary. Nevertheless, this commonsensical notation is sufficient for the current model and processes to be flexible enough to accommodate a variety of linguistic structures (cf. Kintsch, 1972).

The same sentence may be represented differently in different situations. This follows from the assumption that the representation captures the information that a person extracts from a sentence. What information is extracted depends on the preceding sentences, the situation in which the sentence is embedded, and the listener's previous knowledge. In other words, context plays a role in how a sentence is represented, suggesting an important distinction between the psychological notion of an internal representation and the traditional linguistic notion of deep structure.

The task. We have recently proposed a model to account for the mental processes underlying the verification of affirmative and negative sentences (Carpenter & Just, 1974). The situation that originally gave rise to the model is a simple task in which a person must decide whether a sentence is true or false of a picture. For example, Just and Carpenter (1971) presented a sentence like The dots are red or The dots aren't red, as well as a picture of red dots or a picture of black dots. Thus, the sentence could be affirmative or negative, and true or false. A person was simply shown the picture, and then timed to see how long it took him to read the sentence and decide whether it was true or false. The results of this study showed that it took longer to verify negative sentences than affirmative sentences by a certain amount of time, called negation time. In this particular study, the negation time was a little more than two fifths of a second. The study also showed that affirmative sentences were verified

[illegible] [illegible] [illegible] [

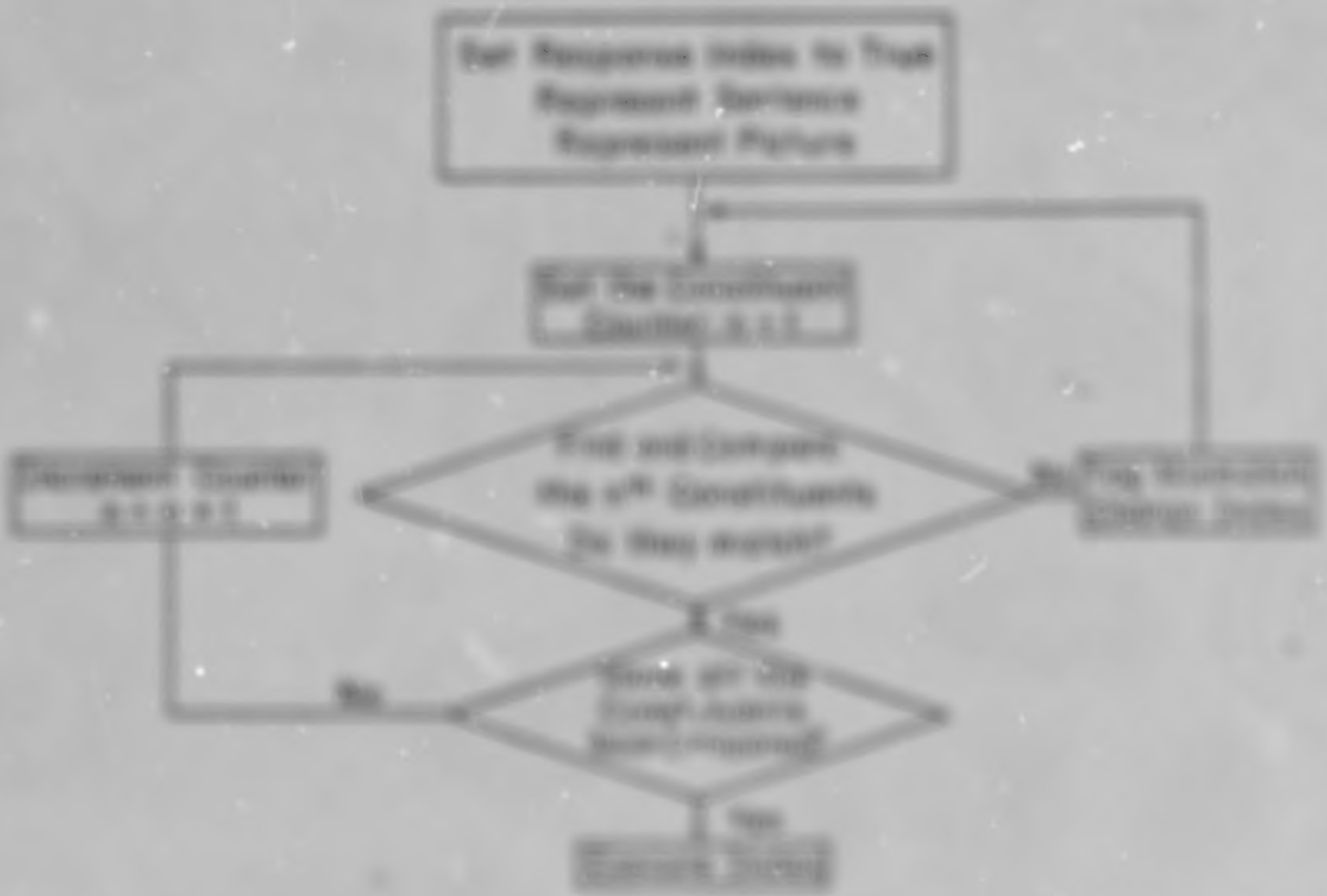


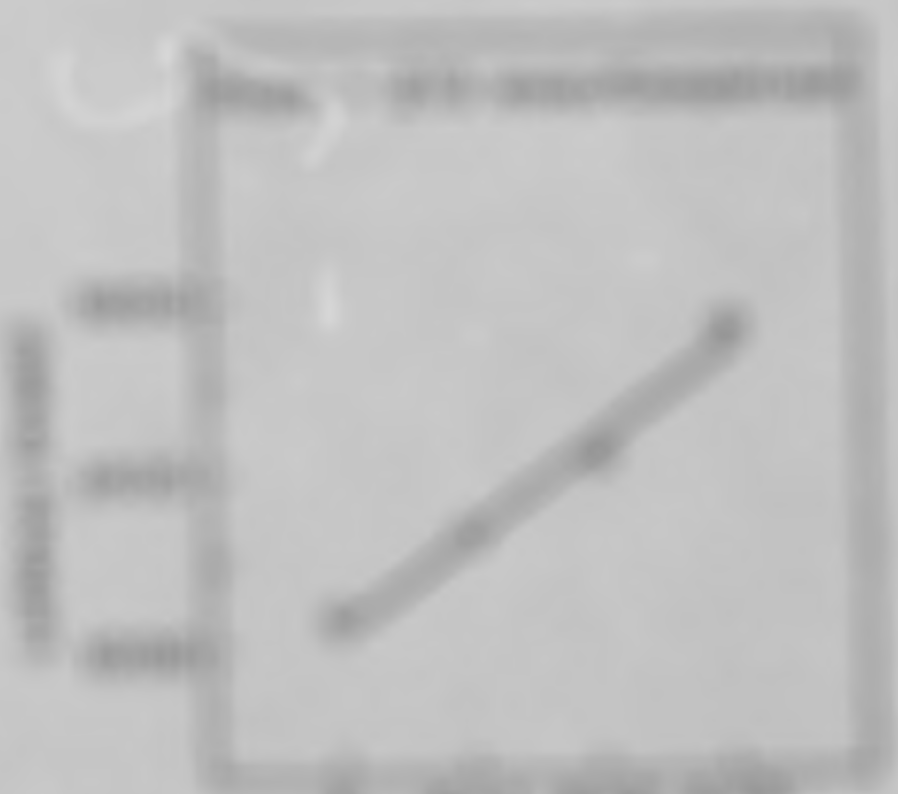
Figure 1

A flow diagram of the comparison algorithm.

[illegible] [illegible] [illegible]

[illegible] [illegible] [illegible]

[illegible] [illegible] [illegible]



The exact predictions can be derived by reviewing what the hypothesized representations for these sentence types are, and how they interact with the comparison process.

The representation of an affirmative sentence like It's true that the dots are red may be the same as for the simple sentence The dots are red, namely, (AFF, (RED, DOTS)). The rationale is that the embedding clause It's true... does not change the truth value and so it can be ignored. To demonstrate this point, consider a concatenation of this type of clause, e.g., It's true that it's true that it's true...the dots are red. The number of such embedding clauses is irrelevant to the truth value of the proposition. Similarly, the embedding affirmative proposition may be deleted from the representation of a predicate negative sentence like It's true that the dots aren't red, so that the representation would be (NEG, (RED, DOTS)). However, the representation of a denial like It isn't true that the dots are red, must include the negative embedding clause. Here the embedding clause does affect the truth value of the sentence. Thus, denial sentences might be represented like (NEG, (AFF, (RED, DOTS))). The pictures would be represented as simple propositions like (RED, DOTS) or (BLACK, DOTS). Table III shows examples of the representations in the six conditions.

The experiment was a verification task in which the person was timed while he read a sentence, looked at a picture, and then decided whether the sentence was true or false of the picture. There were 24 subjects.

Insert Table III about here

The predictions of the model can be derived by examining the flow chart model in Figure 1 and the representations in Table III. The predicted number of operations necessary to verify a true affirmative is k; a false affirmative is k + 1; a false predicate negative is k + 2; a true predicate negative is k + 3; a false denial is k + 4; and a true denial is k + 5. The verification latencies should increase linearly with the proposed number of operations. A

Table III

Representations and predictions for the six information conditions[a]

	True Affirmative	False Affirmative
Sentence:	It's true that the dots are red.	It's true that the dots are red.
Picture:	Red dots	Black dots
Sentence Representation:	(AFF, (RED, DOTS))	(AFF, (RED, DOTS))
Picture Representation:	(RED, DOTS) + + response = true k comparisons	(BLACK, DOTS) - index = false + + response = false k + 1 comparisons

	False Predicate Negative	True Predicate Negative
Sentence:	It's true that the dots aren't red.	It's true that the dots aren't red.
Picture:	Red dots	Black dots
Sentence Representation:	(NEG, (RED, DOTS))	(NEG, (RED, DOTS))
Picture Representation:	(RED, DOTS) - + index = false + + response = false k + 2 comparison	(BLACK, DOTS) - index = false - + index = true + + response = true k + 3 comparisons

Table III continued

	False Denial	True Denial
Sentence:	It isn't true that the dots are red.	It isn't true that the dots are red.
Picture:	Red dots	Black dots
Sentence Representation:	(NEG, (AFF, (RED, DOTS)))	(NEG, (AFF, (RED, DOTS))
Picture Representation:	(RED, DOTS) - + + index = false + + + response = false k + 4 comparisons	(BLACK, DOTS) - index = false - + + index = true + + + response = true k + 5 comparions

[a]Plus and minus signs denote matches and mismatches of the corresponding constituents. Each horizontal line of plus and minus signs indicates a re-initiation of the comparison process.

linear increase in latencies among these six conditions will constitute strong support for the constituent comparison model and the notion of a single underlying iterative operation.

The results showed that, as predicted, the mean latencies increased linearly with the number of hypothesized constituent comparisons. More precisely, latencies increased an average of 200 msec for each additional constituent comparison (Standard Error = 23 msec). Figure 3 shows this result, along with the best fitting straight line. The model accounts for 97.7% of the variance among the six means, $F(1,115) = 171.17$, $p < .01$. The residual 2.3% is not significant, $F(4,115) = 1.01$. The Root Mean Squared Deviation (RMSD) of 52 msec is small relative to the 200 msec parameter. This analysis confirms the major hypothesis that verification time increases linearly with the number of constituent comparisons.

Insert Figure 3 about here

The error rates for the six conditions were correlated with the latencies ($r = .98$), as is shown in Figure 3. This correlation indicates that the probability of error increases with the number of hypothesized operations.

The model is able to predict the processing time for these six conditions on the basis of a single parameter: the time to find and compare a pair of constituents. These results strongly support the hypothesis that a single iterative operation accounts for the processing of affirmative and negative sentences. The embedded representation, combined with the iterative comparison operation, allow the model to account for the two scopes of negation without additional assumptions.

A further control study showed that the representation and processing of the sentence is determined by its semantics, rather than by its surface structure. To show this, we compared the processing of sentences that had the same constituent structure but different surface structures. In this control study, the

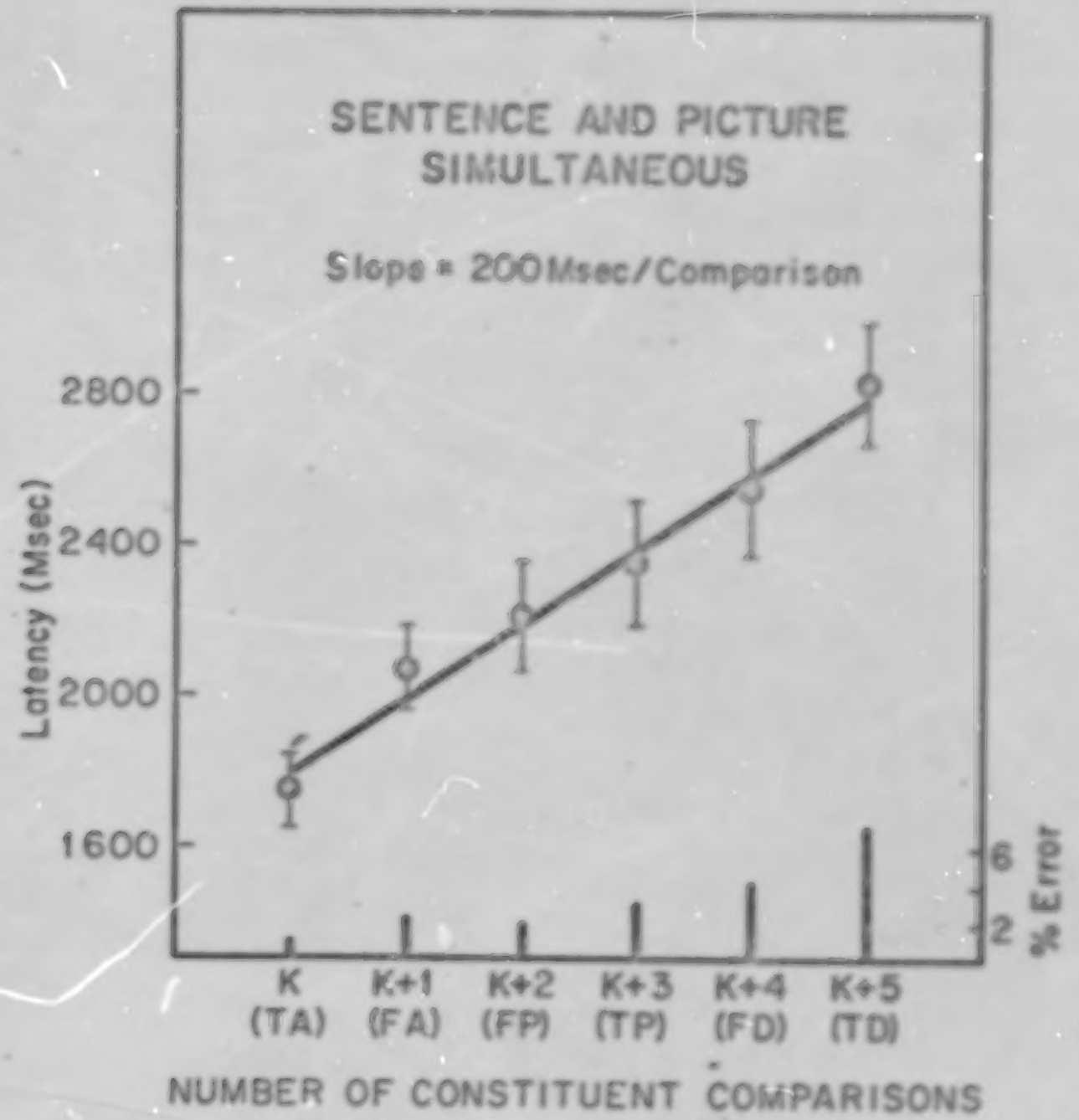


Figure 3

The fit of the constituent comparison model for the six information conditions.

inner propositions of the sentences were embedded in two ways: the same way as the previous experiment (e.g., It's true that the dots aren't red) and with the embedding clause at the end of the sentence (e.g., That the dots aren't red is true). Both of these kinds of sentences are postulated to have the same constituent structure. However, the position of the negation in the surface structure has been changed. If the results of the basic experiment can be replicated with the new sentences, then the results cannot be due to position of the negative morpheme in the surface structure. The new stimulus sentences were: Affirmative -- That the dots are red is true; Predicate negative -- That the dots aren't red is true; and Denial -- That the dots are red isn't true.

This control study showed the two types of surface structures were processed similarly. Both types of sentences showed a linear increase in latency as the number of comparisons increased. Regardless of whether the negative morpheme occurred near the beginning or end of the sentence, denials took about 300 msec longer to verify than predicate negatives. This result shows that the underlying constituent structure rather than order of negatives in the surface structure determines processing time, and constitutes further support for the proposed representations for the two kinds of negative sentences.

The mental processes described by this model are not specific to the sentence-verification paradigm, but occur in a large number of situations that involve verbal comprehension. These more general processes involve relating the information from a sentence to information from a second source, such as the listener's previous knowledge of the world. For example, in order to agree or disagree with a statement, it is necessary to compare the statement to a representation of one's own belief. In order to answer a Wh-question (e.g., Who painted the fence), the information provided in the question (e.g., that someone painted the fence) must be compared to previous knowledge before the interrogated constituent can be retrieved. In order to acquire new information through a verbal

makes, the old information in the comprehension will serve as a basis to which the new information is added. The presentation of these subdimensions is not one only by mode of the sentence representation is compared to previously knowledge. And, in the next section of the paper, we will show that dramatic comparisons sometimes also occur when we follow simple sentences. Thus, a the basic kinds of operations described by the model are part of a large class of comparisons operations that occur very commonly when we comprehend linguistic material.

The mental operations described by the model are not specific to the processing of explicitly negative sentences but rather, they occurred in the processing of a variety of semantic structures. Elsewhere, we have shown how the model accounts for negative structures such as negative quantifiers like few, generalized and universal quantifiers like some and all (Kaup, 2001b), counterfactual clauses like Mary would have left ... (Kaup, 2001), and negative and passive sentences like The cat hit the block and The block was hit by a the cat (cf. Carpenter & Just, 1975). In the next section, we will show how the model also accounts for the processing of sentences that contain implicitly negative predicates.

Comprehending implicitly negative sentences

A number of predicates like forget, disappear, disagree, and dismiss are considered implicitly negative (cf. Kiraz, 2004; Just & Carpenter, 1971; Clark, in press). For example, we may define forget as didn't remember so we may think of absent as not present, and so on. By contrast, we do not usually think of remember as didn't forget. This suggests that dismiss may be an asymmetry in how we internally represent pairs of lexical items like remember and forget, an implicitly negative item like forget may be internally represented as a negation of remember. This hypothesis can be tested by examining the data from a number of comprehension studies that have used such implicitly negative predicates. Two types of studies provide relevant data. The 3 first type

[illegible] sentence combinations were given the subjects concerned appropriate linguistic predicates. On the second type of trial, the experimental task in the instructions given to the subject. If predicates like *forget* are [illegible] or negatives, then there processing should conform to the semantic-based interference model.

Embedded Forms. The experimental linguistic predicates *forget* to provide an interesting opportunity for examining the interpretation of negation. Not only do both predicates negatives, but the preposition embedded in it as once negative. For example, the sentence *John forgot to put the dog out* presents implies that *John didn't put the dog out* (Karttunen, 1971). There are not simple two-place sentential connectives that are [illegible] of implicative linguistic predicates, as Nairn and Karttunen did (1973). In that sense, *Bruce* (1), subjects were presented with an affirmative sentence *John remembered to put the dog out* or the implicative negative one *John forgot to put the dog out* and then were asked to [illegible] Does the probe sentence *Is a. The dog is out* an item in terms of the implications of the premise sentence. For premises affirmative form a sentence like *John put the dog out* is that the dog isn't out. This was true here approximately 90% (Nairn, 1974, 1977). The information from a sentence with *remember* is [illegible] as approximately 10% (Nairn, 1977, 1977). Both sentence representations should be compared to a representation of the probe, like *The dog is in*, approximately 50% (Nairn, 1974, 1977). The model predicts that verification sentences should [illegible] slower than [illegible] to false [illegible], to [illegible] *forget*, to true-*forget*. The data confirm this [illegible] to predictions of the model, which accounts for 96.4% of the variance among the four conditions, as shown in Table 2. This result shows that the implications of negative implicative are processed [illegible] to negatively negative sentences.

[illegible] Table 2 about here

Table 3

Abdominal load tolerance limits for assessing effectiveness

and applicability diagonal lap belts/shoulders

Performance	Designation of agreements	Estimated acceptance limit	Time gain	Number of measurements (independent)			

2. If the payment not credited was made more than four weeks ago, subtract it from the balance due...

3. If you have paid the entire balance due within the last four weeks, please disregard this notice.

Please send us an explanation if the balance is incorrect for any reasons other than payments we haven't credited.

EXPLANATION OF PENALTY OR INTEREST CHARGES

Your return was not filed and your tax was not paid by the due date. The combined penalty is 5 percent of the tax not timely paid for each month or part of a month the return was late, but not more than 25 percent.

This notice is not the result of an audit of your return. When we select a return for audit, we notify the taxpayer.

Presumably the IRS is not interested in testing our comprehension skills.

In other situations, the purpose of a complex instruction is precisely to assess comprehension skills, as illustrated by the following item (Personnel Test, Form D., E. F. Wonderlic).

Count each Z in this series that is followed by an F next to it if the F is not followed by an S next to it. Tell how many Z's you count. ZFZSEYZFSYFZFFSYSZFEZFSFZYFZFY

This is an extremely easy task if one comprehends the instruction, which could have been simplified as follows: Count the occurrences of the sequence (/Z/, /F/, /non-S/) in this series.

There are other situations where the purpose of complex instructions is not clear. The following example is taken from an aptitude test for prospec-

tive students of management science (Graduate Study in Management: A Guide for Prospective Students, Educational Testing Service):

Directions: Each of the data sufficiency problems below consists of a question and two statements, labeled (1) and (2), in which certain data are given. You have to decide whether the data given in the statements are sufficient for answering the questions. You are to blacken space

A. if statement (1) ALONE is sufficient, but statement (2) alone is not sufficient to answer the question asked;

B. if statement (2) ALONE is sufficient, but statement (1) alone is not sufficient to answer the question asked;

C. if BOTH statements (1) and (2) TOGETHER are sufficient to answer the question asked, but NEITHER statement ALONE is sufficient;

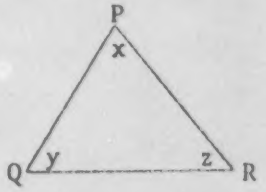
D. if EACH statement ALONE is sufficient to answer the question asked;

E. if statements (1) and (2) TOGETHER are NOT sufficient to answer the question asked, and additional data specific to the problem are needed.

Example: In Δ PQR, what is the value of x?

(1) PQ = PR

(2) y = 40



Answer: C

This kind of instruction seems to be testing both the ability to comprehend instructions, as well as knowledge of geometry and logic. Incorrect answers could be caused by any of these three sources. The relative contribution of comprehension difficulties can be assessed by rewriting these instructions in

a simplified format.

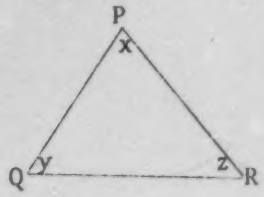
Revised Directions: Answer YES or NO to each of the following questions.

In Δ PQR, can you determine the value of x if all you know is that:

(1) PQ = PR? (Answer is NO)

(2) y = 40? (Answer is NO)

(3) PQ = PR and y = 40? (Answer is YES)



These examples illustrate how successful performance in a test may depend on comprehension skills in decoding the instruction, as well as the content skills that the test ostensibly taps. Thus, both components may enter into the test scores that can often predict future academic performance. It may turn out that the predictive ability of the test is partially due to the comprehension skills it taps, rather than the content skills. If the test is being used only for actuarial purposes, the relative loadings of the two factors are irrelevant. However, if the testing is for diagnostic purposes, then it is necessary to access the relative contribution of comprehension skills before remedial action can be taken. This may prove to be a fruitful approach to test construction.

In many situations, the primary purpose of an instruction is to inform, to help people perform correctly and efficiently. For example, instructions on income-tax forms, or in repair manuals should be constructed to minimize comprehension difficulties. A theory of sentence comprehension, such as we have outlined, suggests the kinds of problems that may arise in representing and executing various kinds of instructions. The theoretical approach also suggests ways of making everyday instructions easier to comprehend.

EDUCATIONAL TESTS OF VERBAL COMPREHENSION

Sentence completion tasks. Another domain in which we can apply our information processing analysis is the sentence-completion task, which often appears in tests of academic achievement or ability. This task involves choosing one of several alternatives that "best" completes a sentence frame. Consider the following example:

Beauty is only skin-deep, but ____ goes all the way to the bone.

a. disease b. blood c. ugliness d. fright

e. liniment (Answer: c)

Although performance in this task depends to some extent upon an adequate vocabulary, much of the processing can be explained in terms of the processes described by the comprehension model.

Many of the items in a sentence completion test have structures that are basically like the example above. These items consist of two parallel clauses of the same syntactic type, although there may be a negative lurking in one of them. The missing item is a constituent of one of the clauses. The connective between the two clauses is either affirmative (e.g., and) or negative (e.g., but). The polarity of the connective, as well as the presence of a negative in one of the clauses, determines whether the missing item should be an antonym or synonym of the corresponding constituent in other clause. In the example above, the negative connective but is a cue that the answer is an antonym of beauty.

A number of examples will give the flavor of the kinds of sentence completion items that involve negative connectives, like yet, but, unlike, whereas, and although (taken from a booklet, Preparation for college board examinations by Henry Regnery Co.).

Unlike his cousin, the artist, who was colorful, whimsical, and erratic, the teacher was prosaic, _____, and consistent.

a. infallible b. commonplace c. objective

d. disorganized e. subtle

Though he was romantic and sensual in his outlook, his life was one of _____.

a. profligacy b. naivete c. austerity d. virtuousity

e. maturity

These conditions are not _____ the nature of women but have grown up in spite of it.

a. intrinsic to b. paramount in c. compelling in

d. immutable in e. extrinsic in

Early in the 19th century, in the South, it had become the fashion to raise only one staple crop, whereas in the North the crops were _____.

a. diversified b. unstable c. fallow d. uniform

e. wild

In this game he was an amateur, not an expert, and thus, for the first time, became a(n) _____ instead of a man of action.

a. connoisseur b. spectator c. lawyer d. pragmatist

e. authority

Linguistic analyses of the clausal conjunction but show that it involves incongruence between the two clauses. For example, but may be used if there is a lexical contrast between the two clauses, e.g., Mary likes school but John hates it. A second use of but involves a contrast between what is stated and what the speaker believes to be the usual connection between the two clauses, e.g., Bill is a politician but he's honest or Dick is a veterinarian

but he doesn't like dogs (cf. Lakoff, 1971; Gleitman, 1965; Fox, 1966). Other connectives are instead, although, in spite of, however, and yet conjoin similar kinds of contrasting clauses.

In an experimental investigation of the completion task, Osgood and Richards (1973) asked subjects to complete sentences like X is beautiful --- dumb or X is old --- wise, with and or but. The two adjectives in the sentence either had the same or opposite affective polarity, which was determined a priori with the semantic differential. As the linguistic analysis would predict, incongruence between the two lexical items was a more favorable environment for but, whereas congruence was a more favorable environment for and.

The comparison model suggests that processes might underlie performance in this completion task. First, the sentence must be parsed into two parallel clauses. Then, the constituents of the clauses, including the coordinate conjunction and polarity markers, are checked serially for their polarity. The number of negatives determines whether it is a synonym or antonym of the provided constituent that is output as a response.

This model of processing can be tested with data collected during the sentence completion task. Hannain (1973) measured latencies while people completed sentences like those in the Osgood and Richard's task, and he also varied the number of explicit negatives in the sentence. For example, a sentence could involve adjectives of similar affective polarity (e.g., Joe was mild--nice) or opposite affective polarity (e.g., Carl was troubled--happy), and could contain either no negatives at all, one negative (e.g., Joe was mild--not nice) or two negatives (e.g., Joe was not mild--not nice).

As might be expected, latencies increased as the number of negatives in the sentence increased from zero to one to two. Furthermore, latencies were shorter when the two adjectives were congruent in affective polarity. This difference was not affected by other factors, such as the number of extra

operations caused by the presence of additional negatives. The results are completely consistent with a process that actively checks the constituents of the sentence. The presence of a negative results in a mismatch between the sentence representation and the affirmative frame with which it is compared. Such mismatches cause extra operations, whose durations are additive. Thus, the basic processes involved in this sentence-completion task are quite similar to the ones involved in comprehending and verifying sentences, although the control structures may be different for the two tasks. Processes in both tasks involve serially examining the constituents of representations, encountering mismatches, and consequently performing additional mental operations. This analysis has attempted to show that performance on a common task from a test of verbal skills can be analyzed in terms of underlying mental operations found in other comprehension tasks.

Potential applications: The reading comprehension test. In this section, we will try to outline the kinds of representations, retrievals and comparison operations in another task involving verbal comprehension, in this case, the reading comprehension test. This task is much more complex than the other ones that we have analyzed. The reading comprehension test involves reading a passage, usually 250-500 words long, and then answering 5 to 15 multiple-choice questions about the passage. The instructions are to first skim the passage for information when it is necessary. The time allotted to read the passage and answer all the questions is usually 1 to 15 minutes. We studied this task by having three subjects express their strategies and thoughts aloud while they performed several reading comprehension tests. Thus, this section represents a preliminary extension of the general approach, rather than an empirically confirmed model.

During the initial reading of the paragraph, the three we studied processed the passage in generally extracted and representation. The subjects

[illegible] that our experiment the learners collaborate to learn passage to answer the questions about the three critical looking back at the passage. In other [illegible]. If the team shows that if subjects are kept from looking the texts, both comprehension and memory for the passage suffers (Rosenfield & Berlyne, 1972; Wanning & Kintsch, 1971). Also, when comprehension memory for information in a passage is normal, there is a need to [illegible] were the information [illegible] (Kaplan & Rosenberg, 1975). These results indicate that the learners collaborative project is [illegible] only to the improvement of the passage.

The second improvement of the passage over previous information about higher-order processes that occur between the learners judgements and the revised judgements. There are processes such as associative and integrative order of events, which are exercises used to evoke [illegible] [illegible] [illegible] and so on. The improvements of individual judgements caused by higher-order processes can be accommodated by a number of improvements between (cf. Kintsch, 1972; Rosenfield, Kintsch & Kintsch, 1971; Thorndyke, 1977). Subjects often missed the occurrence of such higher-order processes without viewing the context of the individual judgements. But on [illegible] the critical reading, I subjects may have remembered that the [illegible] sentence of a scenario event took [illegible], but could not recall the specific [illegible].

The third kind of information extracted during the critical reading is a representation of the information [illegible] to the passage. Subjects needed to create [illegible] that could act as a guidance for a particular part of the passage that a question required specific information. As a result, the process [illegible] the need as an inference maker, and the [illegible] representation acted as an indexing system for their extracted memory. But subjects often took steps to look at the passage for specific information. For example, if a question

[illegible] [illegible] [illegible] [

[illegible]

[illegible]

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CHAPTER II

Remembering the Location and Content of Sentences in a Prose Passage[1]

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Abstract

This paper examines how people remember the location of a sentence in a passage, and how they make use of the locative information in retrieving content information. Subjects read a passage and were questioned about the content or the location of certain items in the passage. Performance was measured by monitoring response latencies and eye fixations. Experiment I showed that subjects rarely retain or use any locative information from disorganized passages that they memorize. By contrast, Experiment II showed that subjects do retain and make use of locative information for both organized and disorganized passages when the passage is in view at the time they are answering the questions. Apparently the locative information provides an index to the spatial distribution of sentences in the passage.

One of the more enigmatic skills reported by experienced readers is the ability to remember where certain information is located in passages and books. This location information may be vague, referring to the beginning, middle, or end of a long book or much more specific, referring to a particular location on a page. Even more puzzling is that location information is usually stored unintentionally. The location information may even be available after the content is forgotten; students sometimes report that even though they cannot recall the answer to a quiz question, they can recall the part of the page in the textbook in which the answer is located. There are some tasks in which location information can be very valuable, namely those in which the total content occupies a large amount of space but is physically available for inspection. In such tasks, the location information can provide an index to the text, making the search process more efficient. This is the case in reading comprehension tests where the reader is allowed to refer back to the passage after reading a question. This study will explore the representation of location information in memory and the unintentional use of location information during visual search in a reading comprehension task.

When people were asked to remember the content of a 13-page prose passage, frequently they could also recall which page contained a particular fact, and what part of a page contained it (Rothkopf, 1971). The probability of recalling the content information was also correlated with the recall of within-page location information. There are at least two different explanations for this correlation. One explanation is that readers may be able to report location information by deducing it from their knowledge of the content. For example, after reading a passage describing a football game, the reader could deduce that information about the opening kickoff occurred at the very beginning of the passage, and the information concerning the final

scene occurred near the end of the passage. An alternative explanation is that readers may explicitly encode the location of a specific piece of information, in this case, the item that the flood waters were pictured near the end of the passage. Such location information may be useful in organizing a representation of the passage content. Both hypotheses are consistent with Bartlett's observed normalization. The former hypothesis deals with deficiencies based on content information contained from long-term memory while the latter hypothesis deals with retrieval comprehension and encoding processes.

Recognition and Recitation (RAPR) extended Bartlett's study by examining the relation between recall of location and recall of content. Recall of content was correlated significantly with recall of location, as in Bartlett's study. Recognition and Recitation also found that asking the subjects the location of the scenes in a content question did not help them recall the scenes. So knowledge of location is certainly not a sufficient nor the recall of content. Briefly, the new studies show: 1) incidental recall of location information is a reliable phenomenon; 2) recall of content correlates with incidental recall of location; and 3) recall of content information is not improved by giving subjects location instructions.

Experiment 1

Experiment 1 was a probed recall experiment designed to provide converging location for monitoring either location or content information. Short prose passages (about 150-200 words long) were used. We presented both coherent passages as well as passages whose sentences were in a scrambled order. While location information can be deduced from the logical structure of a coherent passage, it can not be deduced from the logical structure of a disorganized passage. The main purpose of Experiment 1 was to determine 1) how the organization of the passage influenced on- [illegible] effects

[illegible] the transition differentiation and assess the accurate differentiation and its [illegible] assessment between earlier as a function of the experimental task's average [illegible] to the passages.

[illegible]

[illegible]. Three prose passages from the Comprehension Battery of Diagnostic Reading Assessment (CDRA) and three passages from the Proficiency Diagnostic Test (PDT) were identified as adult-level passages due to [illegible] Each [illegible] assessment materials at the [illegible] of eighth [illegible]. The [illegible] selection of the six passages were administered to students who [illegible] the recognition assessment orders. Each passage was then divided into [illegible] sections. To [illegible] words known between the [illegible] and [illegible] and the accurate and urgent assessment and [illegible] each passage. 1, 2, and 3 [illegible]. Each assessment was given followed by the sentences 1 through 3 on the right-hand margin. Three [illegible] sentences were used in a [illegible] [illegible] both descriptive [illegible]. Table 1 shows one of the suggested passages [illegible] to the [illegible] to administer.

Insert Table 1 about here

Both the measure and inventory of word awareness are [illegible]. Two [illegible] were used for both measures and lexical problem. A yes-word [illegible] "[illegible]" or "[illegible]") [illegible] to the subjects decided to use to [illegible] the [illegible] or to [illegible] which of the three [illegible] of the passage [illegible] this [illegible]. Examples of each type of [illegible] are:

[illegible]

[illegible] problem: [illegible] [illegible] the [illegible] of the [illegible]

[illegible]

[illegible] problem: [illegible] [illegible] the [illegible] of the [illegible]

[illegible]

[illegible]

[illegible]

[illegible] [illegible] [illegible] [

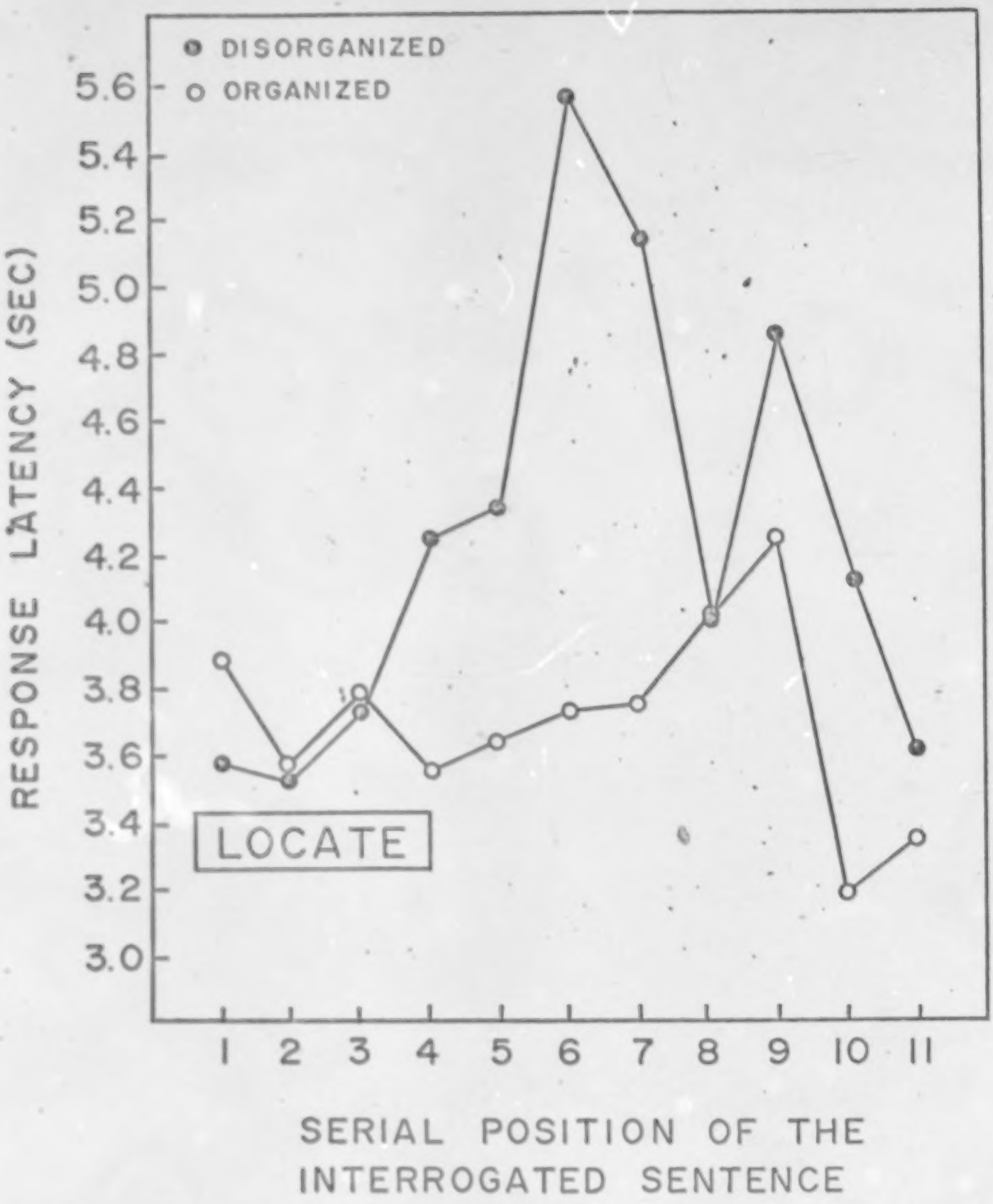


Figure 2. Mean response latencies for Locate probes in Experiment I.

Table 2

Proportion of Erroneous Responses and Don't Know Responses

Response Type	Question Type	Passage Type: Organized	Passage Type: Disorganized	Mean
	Content	.06	.07	.07
Erroneous	Locate	.18	.33	.21
	Mean	.12	.20	
	Content	.13	.11	.12
Don't Know	Locate	.03	.03	.03
	Mean	.08	.07	

in order to retrieve it. This conclusion follows from the pattern of latencies obtained for the disorganized passages. The Locate latencies for the disorganized passages at positions 6 and 7 were substantially (581 msec) longer than the corresponding Content latencies. Since the Locate latencies are longer, retrieving location cannot be a component of the process that retrieves content, at least for these passages. But this is not to say that location information is not used in some situations to help retrieve content information, but merely that it does not have to be used.

The latencies to respond to a Content question were similar for the organized and the disorganized passages. This suggests that subjects may represent the two passages similarly, perhaps by reorganizing the information from the disorganized passages. This in itself is not a startling conclusion, but it does have some interesting implications. It implies that internal reorganization of the sentences of a disorganized passage should destroy some of the locative information in the passage, so that subjects should have difficulty in recalling which part of a disorganized passage a sentence came from. This was certainly the case. The Locate latencies were over half a second longer when the passage was disorganized. This supports the conclusion that the disorganized passage is reorganized in memory.

A third conclusion is that the content of the passage is not stored as an ordered list, for if it were, then one might expect some systematic serial position effects. As Figure 1 shows, there were no systematic serial position effects in recalling the content of either organized or disorganized passages. Rather than a list, the passage content is probably stored as an interconnected network structure, whose nodes are single propositions, and the links are inter-propositional connectives denoting relations like causality or temporal sequence.

Experiment II

Experiment II was designed to unobtrusively measure memory for location by recording subjects' eye fixations as they scanned a previously-read passage in search of an answer to a Content question. Subjects read passages such as those in Experiment I (with location boundaries and sentence rating numbers deleted) solely for information about content. Subjects first read the passage at their own rate and then answered oral questions about the content of the passage. They were permitted to look back at the passage when answering the questions. The subjects' initial fixations should indicate where they thought the desired information was located. This paradigm has several advantages. First of all, the locative information serves a useful function in this task in that it provides an index to the visible passage. Secondly, the locative information should be stored incidently, and made use of without explicit mention of it. Thirdly, the familiar reading comprehension task plays an important role in evaluating academic ability and achievement, so it is an ecologically valid task.

This task requires subjects to compare the probe question to their knowledge about the paragraph and either respond with information stored in memory or search the passage for the answer to the probe. Of central interest to this study is the use of stored locative information in a visual search task. If information about location is available in memory but the corresponding content information is not, the locative information could provide an index to the spatial distribution of information in the passage. Locative information could be used either to fixate the interrogated information in the very first fixation or to guide an extended search consisting of several fixations. Visual search for information in

disorganized passages may take longer either because of lack of locative information or inaccuracy of stored locative information.

A number of measures from the visual search paradigm are of interest in this study. How accurate is the initial eye fixation with respect to the actual location of the probed information? Does passage organization play a role in visual search for information? Do subjects use locative information to guide extensive visual searches? The answers to these questions should provide a clear statement about the use of locative information in reading comprehension.

METHOD

Experiment II made use of the same materials as Experiment I. The main distinguishing properties of Experiment II were (1) only Content questions were asked, (2) the passage was presented on a standard video monitor and the subjects' eye fixations were recorded, and (3) the questions were presented orally.

Eye fixations were monitored with a corneal reflectance eye camera. The eye spot was electronically superimposed on a picture of the stimulus display, and the composite was recorded on videotape for later scoring. The entire passage subtended about 24° of visual angle in the horizontal axis and 19° in the vertical, but this varied from subject to subject as the viewing distance was adjusted between 53 and 68 cm.

Procedure. Subjects were instructed to read the prose passage solely for content with no mention about the location of information in the passage. The test passage was presented on a video monitor. After the self-paced reading period, the passage was switched off the monitor screen. During this off-period the monitor screen was blank. The 11 trials (one for each sentence in the passage) began immediately afterward. The spot

eye calibrated before each trial when subjects were asked to fixate the bottom center of the screen. A trial consisted of a question phase, when the oral probe was presented while the monitor was blank, followed immediately by a visual search phase, during which the passage was presented on the monitor. The visual search phase was terminated when the subject ended his vocal response to the question. At that time, the passage was switched off again. Response latencies were determined by measuring the interval between the end of the question (which was simultaneous with the onset of the passage) and the beginning of the response. The interval was measured with a stopwatch from the audio portion of the recording of the session.

Subjects. The 6 subjects were college students who were paid for one experimental session. Data from four other subjects could not be used because of excessive head movements resulting in unstable eye specs. All subjects had normal, uncorrected vision and wore no corrective lenses.

RESULTS

Subjects remembered the location of the interrogated sentence quite well. After they heard the question, their initial fixation on the passage was at the interrogated sentence 91% of the time for organized passages, and 19% for disorganized passages. Chance level is 9%. Figure 3 shows the mean location initially fixated as a function of the serial position of the interrogated sentence. The data indicate that even when the first fixation is not at the correct location, it is generally close to the correct location. If the subjects' first fixation were always at the correct location, then their data would fall along the dashed diagonal line in Figure 3. As it is, they are fairly close. One of the points plotted in Figure 3 deserves special mention. The mean initial fixation location for serial position 3 of the disorganized passages seems to be

discrepant. However, there is a very interesting relationship between these data. Some of the passages contained words that are central to the particular character. Consequently, when the probe asked about that character, there was more than one appropriate location to fixate in the passage, although only one location was "correct" in the sense that it contained the answer to the probe. Almost all the "incorrect" fixations on initial positions 3 for discrepant passages are accounted for by this factor. The result suggests that subjects did access an appropriate location even for the condition that appears at first to be discrepant.

Insert Figure 3 about here

The accuracy of the first fixation is similar for the organized and disorganized passages. However, when the initial fixation was inaccurate, the subsequent search was much more efficient for the organized passage. This was demonstrated by counting the number of fixations before the response was made. In this analysis, any consecutive fixations on the same position were considered as a single fixation. A change in fixation was scored only if there was a vertical change in eye fixation position, namely from one word to another. As Figure 4 shows, visual search is facilitated when the passage is organized rather than disorganized. On average, there are about 1.5 fewer fixations for the organized passage. The relative advantage of the organized passage is more apparent for the middle serial positions.

Insert Figure 4 about here

The response latencies in this task presented an excellent opportunity to examine the role of location information in this application to the reading comprehension task. If the answers to the questions are retrieved such as the answers to a memorized passage are, then the required location

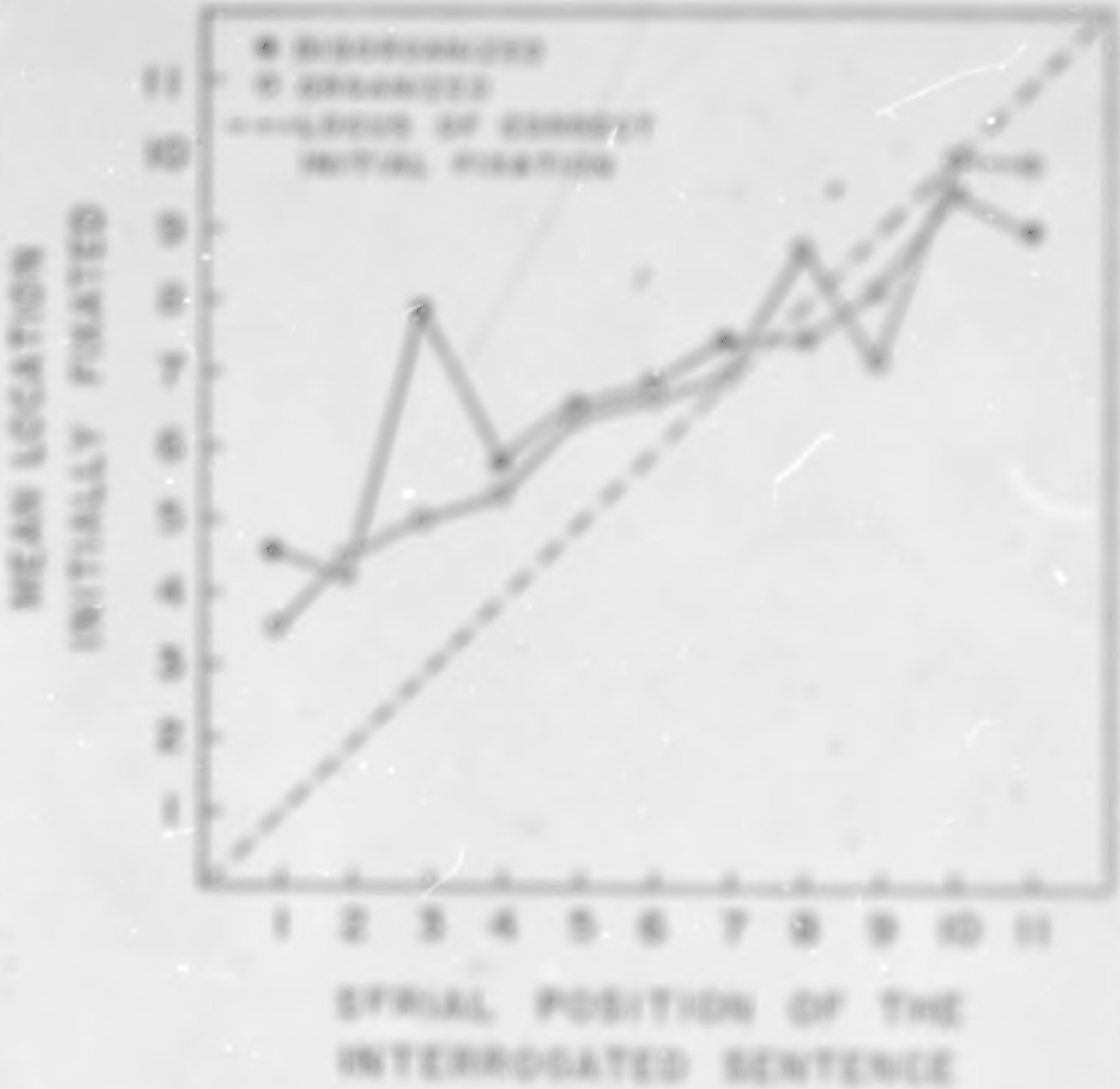


Figure 1. Mean locus of the initial fixation as a function of the serial position of the interrogated sentence in Experiment 1.

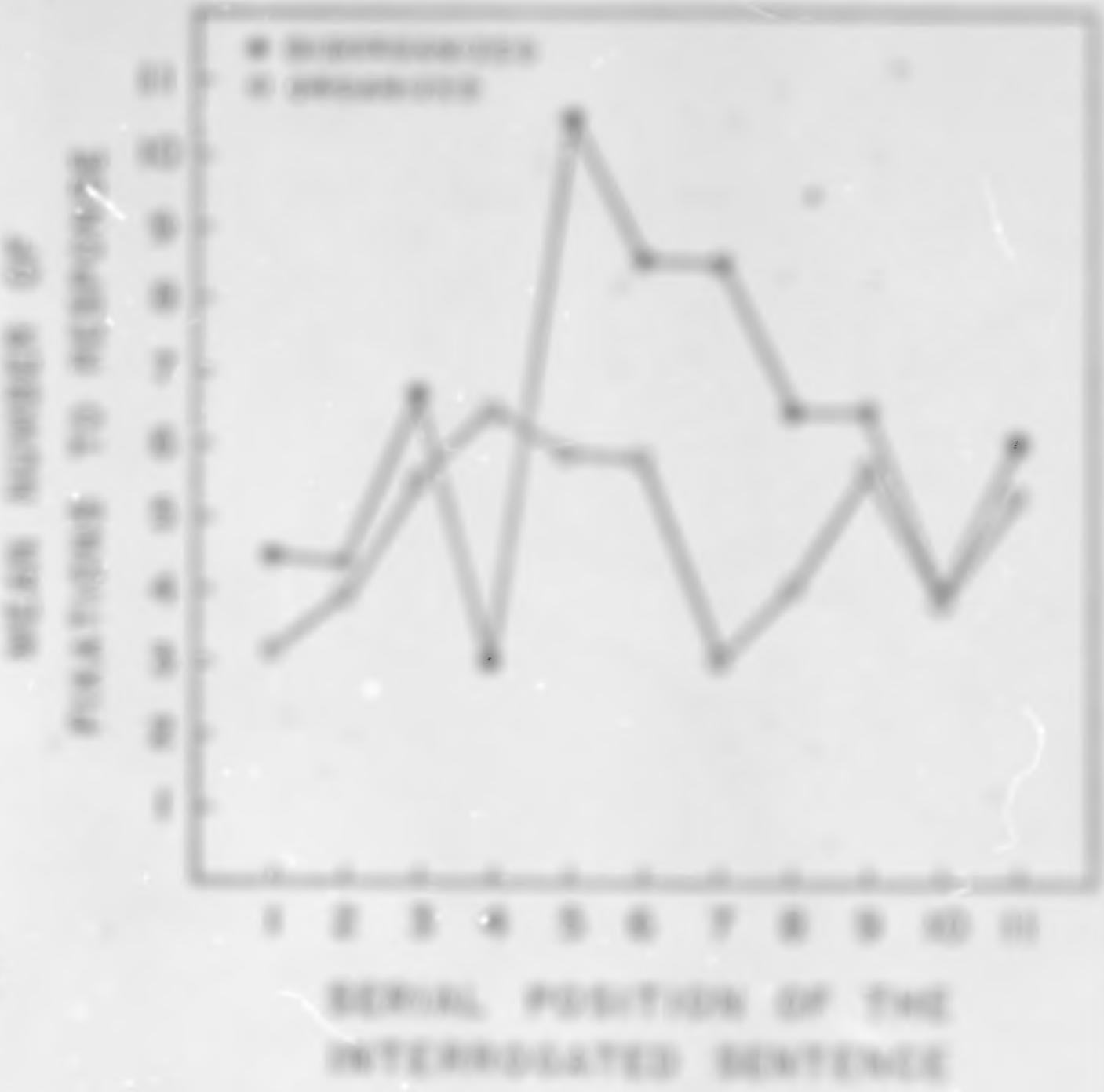
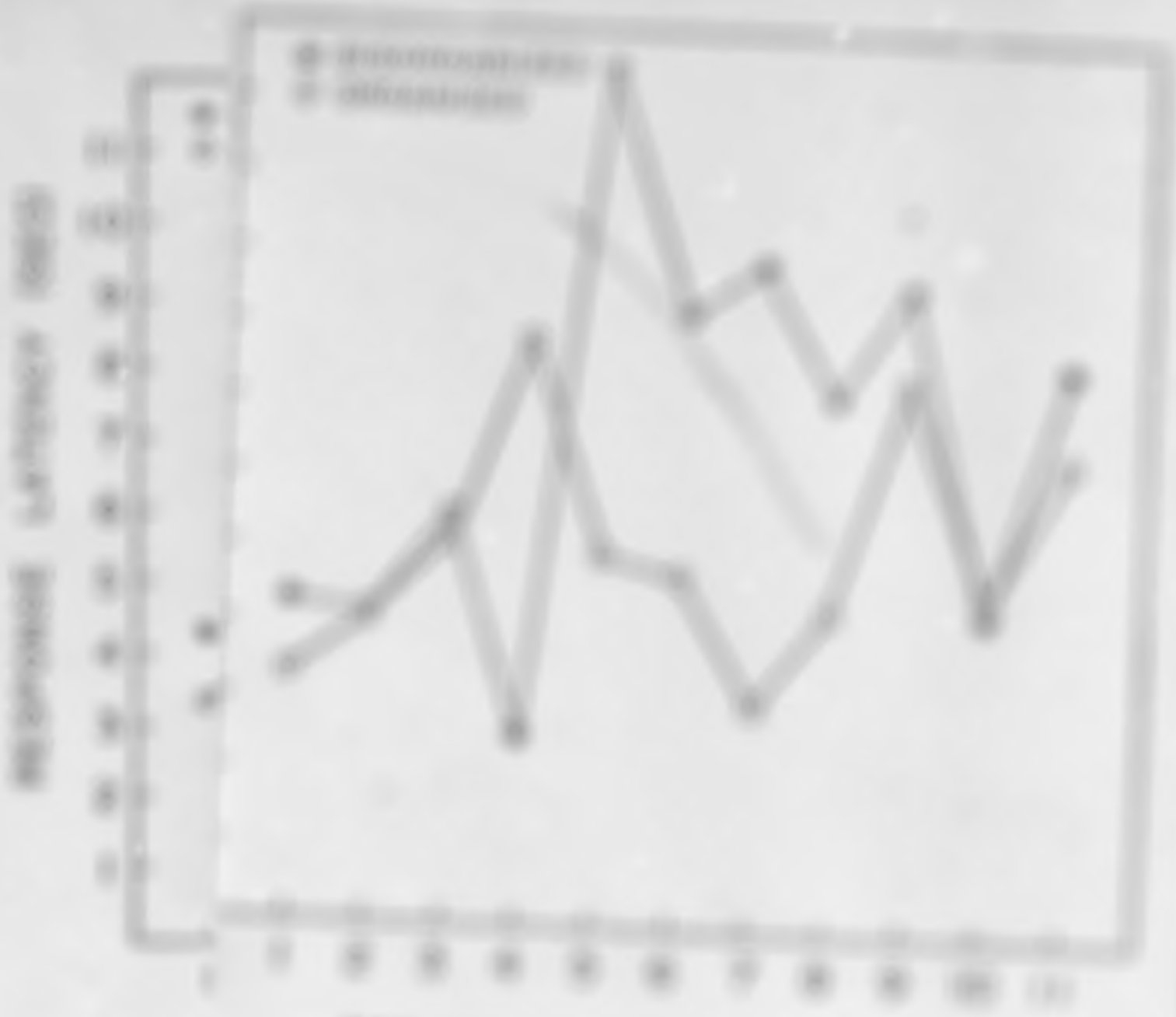

MEAN NUMBER OF
PARTICIPANTS TO RESPONSE
SERIAL POSITION OF THE
INTERROGATED SENTENCE

Figure 1. [illegible]

[illegible] [illegible] [illegible] [



(b)

FOOTNOTES

1. This research was supported in part by Research Grant NIE-G-74-0016 from the National Institute of Education, and Grant MH-07722 from the National Institute of Mental Health. We thank Patricia Carpenter for her comments on the project. Requests for reprints should be sent to Marcel Adam Just, Psychology Department, Carnegie-Mellon University, Pittsburgh, Pennsylvania 15213.

2. Now at the Department of Psychology, Stanford University, Stanford, California.

3. We thank Tom Donlon of Educational Testing Services for providing this material.

CHAPTER III

Integrative Processes in Comprehension[1]

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To appear in: D. LaBerge and S. J. Samuels (Eds.), Perception and Comprehension. Hillsdale, N.J.: Lawrence Erlbaum Associates, 1976 (in press).

Even though we acquire much of our knowledge by reading or listening to other people, we sometime have difficulties in understanding them. The problem often lies not in understanding the words that the other person is using, but in understanding "what the speaker is talking about." These difficulties arise in understanding how the words and clauses in a sentence are related to other sources of information, such as the previous sentences in the discourse. One example of this interrelation among sentences is the use of a pronoun to refer back to a previously mentioned item. For example, if the sentence He just bought a car occurs within a paragraph, then the referent for he must have been previously established. Comprehension in context requires more than understanding that he refers to an animate male, probably human. It requires that the comprehender determine the referent of he. This is an example of what we mean by relating the information in the sentence to other knowledge in order to understand "what it is about." This paper will examine the process by which the information in the sentence is related to other sources of information, such as a preceding paragraph, a question, or the perceptual context. We will also examine a number of linguistic devices that indicate how the sentence is related to its context; and how the linguistic cues are used during comprehension.

To talk about the psychological process of integrating information,

we will introduce the concept of a discourse pointer. A discourse pointer is a symbol in the comprehender's mind that indicates the current topic of the discourse or the perceptual context. The discourse pointer activates either a single concept or an entire relational structure. The activated constituent then plays a central role in how the currently comprehended sentence is integrated with other information. We will show that the function of a number of linguistic devices used in discourse is to set the pointer appropriately. The appropriate placement and movement of the pointer during discourse makes sentences of a well-written paragraph seem to flow smoothly.

While we will primarily discuss integrative processes from the viewpoint of psychological processes and linguistic structures, we will also discuss the integrative devices from a third viewpoint--namely the rules for writing comprehensible prose. Teachers of prose composition have provided some rules of "good writing". These rules are often concerned with the linguistic devices that make sentences fit together. We will show how their analyses are based on implicit models of human comprehension processes. Many of the guidelines can be thought of as rules for setting the discourse pointer of the reader. We will examine these rules and relate them to psychological models of the reader's comprehension processes.

As an initial example of the psychological function of the discourse pointer, consider the process of comprehending a very simple paragraph:

> Cecil, the aardvark, was a perfect pet. Because of his exotic eating habits, he was able to rid the house of

> insects. What he devoured most often were the fat, juicy ants. Moreover, he was an affectionate animal. However, because of his ugly snout, he was difficult to love.

Various linguistic devices in this paragraph set the discourse pointer and indicate how the sentences relate to one another. The opening sentence initially sets the discourse pointer to the proposition that the aardvark is a good pet. Opening sentences play a major role in paragraph comprehension because they determine the initial state of the pointer. The initial state may also serve as a default state, to which the pointer returns unless it is explicitly set to another concept or proposition. That is why it is important to place topic sentences at the beginning of paragraphs.

The second sentence exploits the preceding context by referring to the aardvark with the pronoun *he*. The discourse pointer moves to a pair of propositions that describe the nature and consequences of the aardvark's eating habits. The third sentence presupposes that Cecil devours things. This presupposition matches the contents of the discourse pointer. The third sentence also adds the new information that the insects most often eaten are ants. The comprehension of this sentence depends upon already having established that Cecil eats insects. The connective *moreover* signals a return to the main line of argument about Cecil's good pet qualities. The *however* in the final sentence signals an opposing argument to the thesis that Cecil is a good pet. Thus, the reader is given an indication of how to relate the sentence to the representation he has constructed from the previous discourse. This short paragraph provides a number of examples of linguistic devices that

determine the relations between sentences. This paper will explore these devices in terms of how they interact with the discourse pointer during integrative processes.

This paper consists of two main sections. One section will present a series of studies examining how the information designated by the discourse pointer influences the comprehension of a sentence. A second section will examine various linguistic devices that make prose comprehensible and memorable. But before discussing integrative processes, we will first examine some of the methodological issues that arise in organizing the diversified research on comprehension.

Psychological processes and experimental paradigms

In order to interrelate the numerous research approaches to prose comprehension and memory, we have devised a taxonomy (shown in Table 1) that has two dimensions. One dimension concerns the psychological processes of interest, namely comprehension processes or memory processes. The second dimension concerns the particular performance that is measured, for example reading time or amount of recall.

- - - - - - - - - - - - - -

Insert Table 1 about here

- - - - - - - - - - - - - -

The distinction made by the first dimension between ongoing comprehension and memory is more complex than it first appears to be. Comprehension refers to processes that operate at the time of input, while memory refers to the storage and retrieval of the comprehended information. The complexity is that what is stored depends on what was comprehended. Thus, performance in a memory task may reflect either comprehension processes or subsequent memory processes or both (cf., Fillenbaum, 1973). For example, recall or recognition memory for a

Table 1

Processes and Performance Measures in Prose Reading

Processes	Performance Measures
Reading comprehension	reading time
	verification time
	backtracking (eg on wh-NP/S)
	eye fixations
	protocol analysis
Memory	probe (at fixed points)
	recognition memory
	answering questions about a text

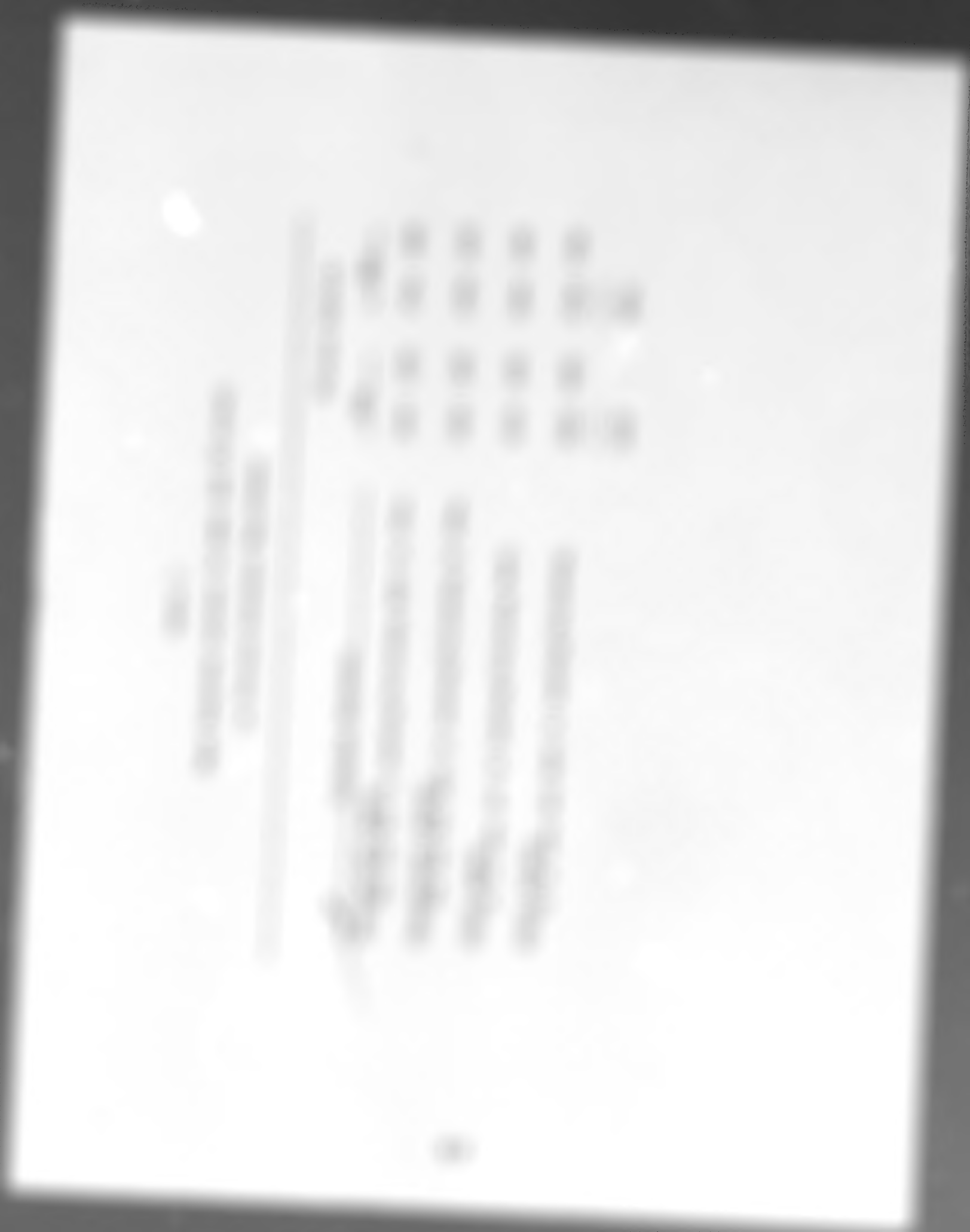
passage and reflect the output of integrative processes in comprehension of the subject of constructive processes in recognition.

Some of the performance measures listed in the second dimension of the taxonomy are especially suited to the study of integrative processes during comprehension. The mental operations of adult learners are those that find and represent higher-order relationships between constituents such as clauses and sentences. The duration of these integrative processes in text users, under optimal circumstances, is the time used a function of a concept in terminating how one sentence is related to another. In order to say more about rapid mental connections, it may be necessary to monitor the processes as a sentence is being read and integrated with the previous ones. The eye-movement can be registered by this chapter) when the reader is read each succeeding sentence of a passage and decide if it is consistent or inconsistent with the previous sentences. The decision times can be registered as a function of the semantic and anaphoric relations between the current sentence and previous ones. This methodology gives some measure of the duration of an integrative step. Another possible approach is to monitor eye fixations during reading. The duration of fixations on a particular connection may reflect how long it takes to retrieve that constituent or previous information from the passage. Furthermore, regressive eye movements to previous sections of a concept may accompanies the search for the constituents to be integrated. To diversify monitoring for integrative process, these methodologies may reveal the nature, sequence, and duration of the mental operations that are used in integration.

Retaining new information in its relationship

Each sentence of a connected discourse includes with some new

[illegible] [illegible] [illegible] [



simple actives, which they resemble. Such an interpretation would be consistent with the obtained result.

In general, performance is facilitated when the old-new information structure of the sentence corresponds to what is pragmatically old and new to the reader. The previous context establishes what information is pragmatically old. In the current task, the reader knew that two people were walking in a line. The picture established the direction of walking and the identity of one of the people. Thus, a picture such as the one in Figure 1 would set the discourse pointer to the propositions (WALK, BARB) & (LEFT, WALK). The information marked as old in a succeeding sentence should be compatible with the contents of the discourse pointer. For example, the information marked as old in The one who is leading Barb is John is that Barb is being lead. The fact that Barb is being lead can be related to the contents of the discourse pointer because they both concern Barb's position. The next step is to add on the new information in the sentence, namely that John is ahead.

The integrative process is more difficult when the sentence is inappropriate to the pictorial context. For example, when preceded by the picture in Figure 1, the sentence The one who is following John is Barb is inappropriate. The information marked as old in this sentence is that John is being followed. It is difficult to relate this fact about John to the discourse pointer, which concerns Barb's position. The reader must discover this mismatch and reinterpret the sentence before adding on the new information in the sentence. It is this mismatch and reinterpretation that results in the longer latencies for sentences that are inappropriate to the context.

The discourse pointer in paragraph comprehension

The discourse pointer should play an especially important role in integrating the sentences of a paragraph. In particular, the setting of the discourse pointer by an early sentence should influence the comprehension of subsequent sentences that refer back to it. To study this comprehension process, we monitored the integration of each successive sentence of a paragraph. The sentences were presented and removed one at a time, and the subject was asked to judge whether each sentence was consistent or contradictory with the preceding sentences. The response latency should provide a measure of the integrative process. We varied the semantic relation between an early sentence and a subsequent sentence and examined the effect of the relation on the response latency. We constructed 32 simple paragraphs that shared certain structural properties; a typical paragraph is:

1. The ballerina captivated a musician in the orchestra during her performance.

(target) 2. The one who the ballerina captivated was the trombonist.

3. It was the conductor who arranged the choreography.

4. The ones who prepared the show had worked long hours.

5. It was the stagehand who arranged the choreography.

The opening sentence always described how a person interacted with some unspecified member of a group. In the example above, the ballerina interacted with an unspecified member of the orchestra. This sentence initially set the discourse pointer to information that was relevant to a later target sentence. The target sentence provided new information as to the identity of the member of the group. In the example above, the target sentence appears in position 2 and specifies that the orchestra

member was the trombonist. This target sentence was to be integrated with the opening sentence. A target sentence with a congruent information structure marks as old the information that had been communicated in the opening sentence. For example, the congruent target in the paragraph above marks as old the fact that the ballerina captivated someone, a fact communicated in the opening sentence. An example of an incongruent target would be The one who captivated the trombonist was the ballerina; this sentence incorrectly marks as old the fact that the trombonist was captivated by someone. In the latter case, the reader must detect the incongruity and reinterpret the sentence before integrating the new information.

A second way in which we varied the relationship between the discourse pointer and the target sentence was by inserting intervening sentences between the opening sentence and the target. That is, the target sentence could appear in positions 2, 3, 4, or 5. The filler sentences were only tangentially related to the opening sentence. The intent of the slightly incoherent filler sentences was to dislodge the pointer from the representation of the opening sentence. Thus, when the target sentence was separated from the opening sentence by fillers, its old information would not be compatible with the contents of the discourse pointer. The reader would be forced to search his memory to retrieve the relevant information. The duration of the search process should be reflected in the duration of the subject's response latency.

The subject was timed while he read each successive sentence of a paragraph on a video monitor and decided whether it was consistent or contradictory with the previous sentences. On a contradictory trial, a filler sentence contradicted one of the previous fillers (for example,

in the paragraph above, the sentence in position 1 contradicts the sentence in position 2). The contradictory fillers never preceded the target. Each paragraph contained at least one contradictory sentence except in cases where the target occurred in the final position. The fillers, like the target, were clefts and pseudoclefts sentences. Therefore, the superficial form of the messages could not differentially cue the subject to the target sentence. Our subjects did not report discriminating between the various fillers and the target, nor did they guess the intent of the experiment.

The paragraphs were randomly assigned to the 12 different conditions, composed of three orthogonal factors: (1) the target sentence had an information structure that was congruent or incongruent with the opening sentence, (2) the target sentence was a cleft agent, cleft object, pseudocleft agent, or pseudocleft object; and (3) there were 0, 1, 2, or 3 filler sentences between the opening sentence and the target. The 12 subjects were college students.

Results. Subjects took less time to integrate the target sentence when its information was congruent with the opening sentence, as shown in Figure 2. Overall, sentences with a congruent structure were verified about 1.4 sec faster than sentences with an incongruent structure, $F'(1,41) = 7.91$, $p < .01$. (The F' statistic is used to test the reliability of this effect over populations of subjects and paragraphs). The information structure of the sentence being processed provides an important cue for relating the sentence to the preceding discourse. The reader uses the information that is marked as old to determine how the current sentence relates to some aspect of the discourse. When this old information matches what is designated by the discourse context, the

[illegible] process is relatively fast. The [illegible] needed to add on the [illegible] of the information worked on did on the same [illegible] does not match the [illegible] of the diagram [illegible] search through the memory representation of [illegible] then the information structure in [illegible] did does not match any of the propositions [illegible] sentence must be reinterpreted before it can [illegible] with the previous information. Consequently, [illegible] have longer response latencies.

* * * * * * * * * * *

[illegible] Figure 3 [illegible]

* * * * * * * * * * *

In cases where the target sentence [illegible] sentence, this experiment resembles the [illegible] with a congruent or incongruent information. In that experiment, the advantage of congruent [illegible] considerably less than the 2.5 sec in the [illegible] were no intervening fixture. The possible [illegible] in magnitude in that the sentences in the [illegible] as specified dimensions from trial to trial. [illegible] information appeared, the subject may have [illegible] given the sentence in order to integrate it [illegible] picture. By contrast, the various experimental [illegible] reason to vary different topics. It would [illegible] find the relevant information in memory, and [illegible] find the incongruent structure in the [illegible]

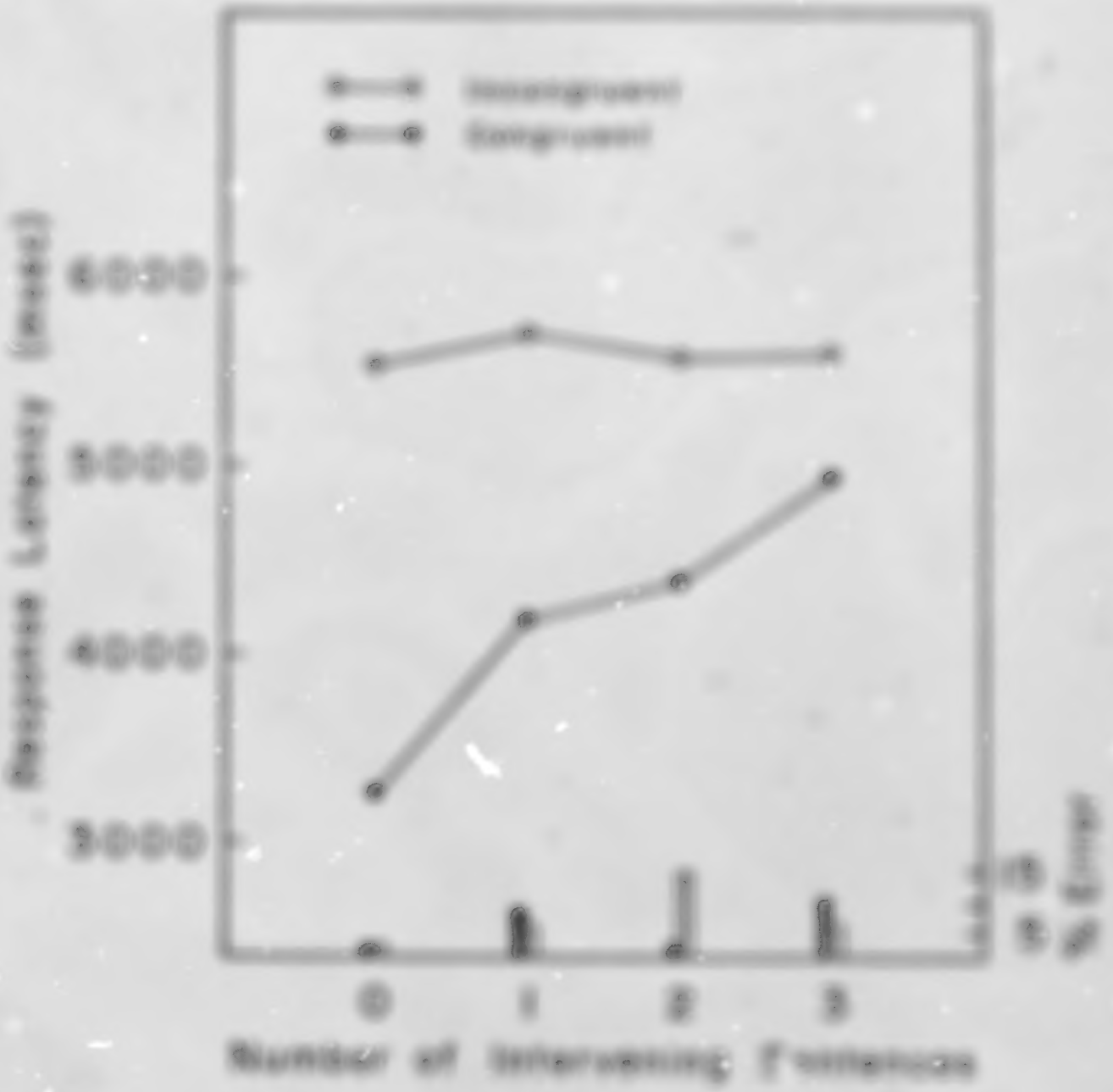


Figure 1. The mean response latencies for congruent and incongruent sentences presented as a function of the number of saccades intervening between the opening sentence and the target.

[illegible] of the proposed load equation the effect of [illegible] processes on [illegible] data.

In the proposed load [illegible] analysis process [illegible] the number of [illegible] determining [illegible] the [illegible] [illegible]. There are as such [illegible] when the weight [illegible] [illegible] [illegible], [illegible] the [illegible] for [illegible] [illegible] [illegible] have highly [illegible], that [illegible] to [illegible] [illegible] [illegible]. However, [illegible] the [illegible] [illegible] of the weight [illegible] [illegible] [illegible] [illegible], [illegible] [illegible] [illegible] the number of [illegible] [illegible], as [illegible] in Figure 1. [illegible] [illegible] [illegible] [illegible] the [illegible] [illegible] and the weight, the [illegible] [illegible] [illegible] [illegible] [illegible] [illegible], [illegible] [illegible] [illegible] [illegible]. [illegible] [illegible] [illegible] [illegible] [illegible]

also influence the way the sentence is related to perceptual events that follow? To examine this question, we designed an experiment in which subjects read a sentence describing the relative positions of two people, followed by a schematic array that depicted two people walking in a particular direction. The task was to verify if the sentence was true or false of the picture. An example of a true sentence and the accompanying picture is:

The one who is leading Dave is Jill.

Jill ← Dave ←

The array consisted of a woman's name, a man's name, and two arrows to indicate the direction in which each of them was walking. The woman in the array was always located on the left, and the man on the right, as shown. Thus, the subject always knew where to look for information corresponding to the new or old constituent. We were interested in whether the subjects would first check the information marked as new or the information marked as old in the sentence.

The main contrast we wanted to make concerned the cases when the picture falsified the information marked as new and those in which it falsified the information marked as old. An example of a display that falsified the new constituent would be:

The one who is leading Dave is Jill.

Sue ← Dave ←

An example of a display that falsified the linguistically old constituent would be:

The one who is leading Dave is Jill.

Jill ← Mike ←

Let us assume that the sentence-picture comparison proceeds roughly as follows. First, the name of one of the people mentioned in the sentence is compared to the name in the corresponding slot in the picture. If the names mismatch, the comparison can terminate with a response of false. If the names match, then the other pair of names is compared. If they match, then the verb can be compared to the relation depicted in the picture. If the comparison process does terminate on a mismatch, then the response latencies can indicate the order in which constituents are compared. Specifically, mismatches on constituents compared first will yield shorter response latencies than mismatches on constituents compared second. Thus, the relative response latencies for the two kinds of false trials should indicate whether the information marked as old or new is compared first.

There were 48 distinct sentence-picture combinations, composed of the four types of sentences (cleft agent, cleft object, pseudocleft agent, and pseudocleft object), whether the new information referred to a male or a female, and 6 different pictures. Three of the pictures correctly depicted what was described in the sentence. The other three pictures falsified the sentence by mismatching the agent, the object, or the verb. Different pairs or triplets of names were used in the 48 trials. Twelve college students ran through three blocks of 48 trials.

Results. The main result was that latencies were shorter when there was a mismatch on the new information than when there was a mismatch on the old information. This result held for all four sentence types as shown in Table 4. The mean difference was 167 msec, $t(11) = 2.90$, $p < .01$. This result suggests that people first compared the new information from the sentence to the appropriate part of the picture.

If there was a mismatch, then the comparison process terminated and there was a quick response. If the new information matched, then they went on to compare the old information. If it mismatched, then the comparison process terminated.

- - - - - - - - - - - - - - -

Insert Table 4 about here

- - - - - - - - - - - - - - -

In a follow-up study, we looked for an overt difference in the perceptually encoding of elements in the display, as a function of the sentential information structure. We designed an experiment very similar to the one above, except that the subject heard the sentence and we monitored his eye movements while he scanned the perceptual display. There was a significant tendency to look first at the part of the display that contained the element corresponding to the word marked as new. For example, when a female name was marked as new, the subject tended to first fixate on the part of the display that contained the female name. This result confirms the conclusion from the latency study, that new information is verified first.

These results are consistent with a study that used a very different methodology. Cleft and pseudocleft sentences like The one who is petting the cat is the girl were presented auditorily, and followed by a picture presented for only 50 msec (Hornby, 1974). The subject's task was to decide whether the sentence was an accurate description of the picture. The false pictures incorrectly depicted either the constituent marked as old or the constituent marked as new, as shown in Figure 3. Of key interest were the false cases that were erroneously labelled "true" by the subjects. Subjects made significantly fewer of these errors when

Table 4

Mean Response Latency and (% error)

in Sentence-Picture Verification Experiment

Stimulus Sentence	Picture Falsifies New		Picture Falsifies Old	
Pseudocleft agent				
The one who is leading/following Barb is John.	2917	(1%)	3180	(0%)
Pseudocleft object				
The one who Barb is leading/following is John.	3020	(0%)	3228	(0%)
Cleft agent				
It is John who is leading/following Barb.	2680	(0%)	2821	(0%)
Cleft object				
It is John who Barb is leading/following.	2880	(8%)	2933	(0%)
	2874		3041	

the picture falsified the new information than when it falsified the old information. If the information marked as new were verified first, then the representation of the picture would still be fresh during verification, and verification accuracy would be high. This representation would decay with time, so that when the subject subsequently verified the old information, his accuracy would decline.

- - - - - - - - - - - - - - -

Insert Figure 3 about here

- - - - - - - - - - - - - - -

The order in which the constituents are verified in all these studies may be explained by considering the normal communicative function of the old-new distinction. When information is marked as old, it is a signal to the reader that he already has identical or very closely related information stored in memory. Normally, he should not have to check whether it is true of the perceptual environment. By contrast, when information is marked as new, it is a signal to the reader that he has not yet heard this particular bit of news. Thus, it might well be subjected to a validity check before being integrated into memory. Thus evidence pertaining to information marked as new is verified before evidence pertaining to information marked as old.

Using the discourse pointer in writing

Stylists and writing teachers have evolved certain guidelines for writing good prose by analyzing examples of good and bad writing and by relying on their own trained introspections. These rules are often compiled in books with titles such as "The Art of Readable Writing" or "How to Speak, Write, and Think More Effectively." The rules concern the kinds of words or sentences that a writer should use, as well as more

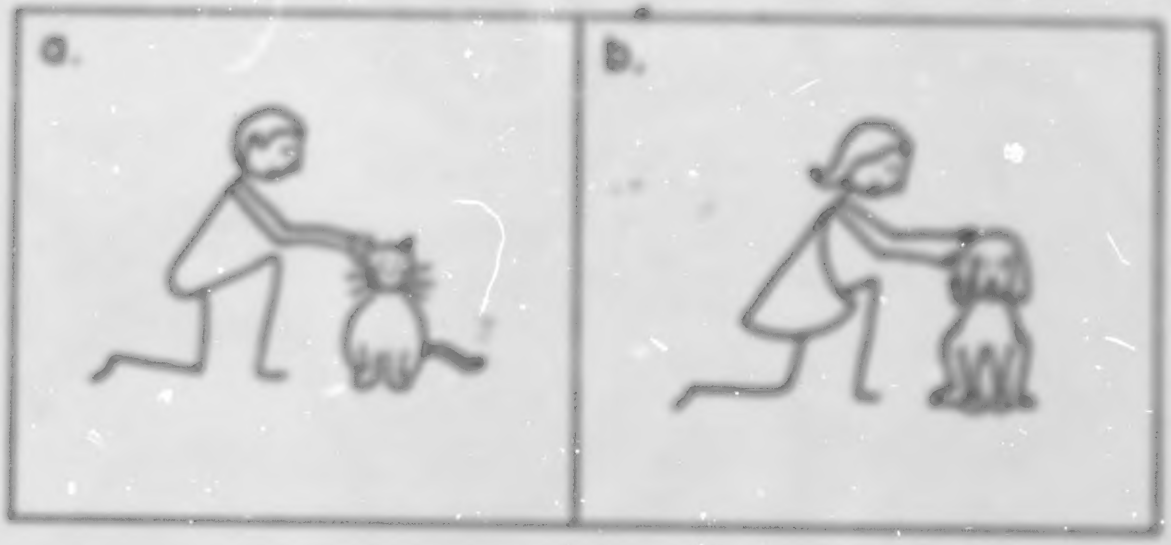


Figure 1. Two pictures that might follow a sentence like The man /is/ is petting the cat /is the girl/. Picture (a) falsifies the new information in the sentence. Picture (b) falsifies the old information.

global guidelines for organizing various aspects of text. In this section, we will be concerned primarily with rules for which sentence the insertion. We will also look into some rules and principles given that facilitate the reader's comprehension.

The serial order of old and new information

The processing distinction between old and new information that we have mentioned has also been discussed by psychology teachers. In particular, they have been concerned with the serial order in which the old and new information occur. One standard guideline is to put old information at the end of a sentence. For example, Haviland and Clark (1974) advise writers to "place the emphatic words of a sentence at the end."

> The proper place to put sentence stress is on the word or group of words that the writer wishes to emphasize by placing it at the end. The end [= position] of each sentence is the position of prominence in which the logical predicate, that is, the new element in the sentence, [...]
> (Haviland & Clark, 1974, pp. 26)

Similarly, Flesch (1946) advises writers to "[b]egin the sentence, from the familiar to the new." Both stress psychological assumption is that the old information will establish a framework. Establishing this framework is equivalent to a directive for the processor to a particular concept before processing the new information. After the process has been set, it is easier to integrate the new information with the previous context.

To summarize that we can have an explicit ordering of the old and new information, the information at the end of the sentence is usually considered to be new (Halliday, 1967). For example, in a simple active,

[illegible] [illegible] [illegible]. [illegible] [illegible] [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

The blacksmith was skilled and he pounded the anvil which was dented.

After listening to a series of such sentences, the subjects were given prompt words and were asked to recall the gist of the sentences. Recall was better in two ways when the sentence had pronominal reference than when it was conjoined with and. First, subjects recalled more words from the pronominal sentences. Second, they recalled more words of the clause that didn't contain the prompt word. This latter result is important because it suggests that the information from the two clauses was more likely to be integrated in memory when a pronominal referent linked them.

The definite article the is another type of anaphoric reference, one that can indicate that the modified noun has been referred to in the preceding context. By contrast, the indefinite article a often modifies a noun whose referent is new (cf., Karttunen, 1971). The role of the article is especially important within discourse, since choice of definite or indefinite article may signal whether two nouns are co-referential. For example, the sentences Yesterday, Lou sold her Chevy. Today, Glen bought the car imply that the same car entered into both transactions. The sentences would have a very different meaning if the indefinite article a replaced the: Yesterday, Lou sold her Chevy. Today, Glen bought a car. Hence, the definite or indefinite articles tell the listener how to integrate the two clauses.

The indefinite article, like a pronoun, assumes that the referent exists. As an example, consider the following sentences from Karttunen (1971):

(1) a. Bill has a car.

b. It is black.

c. The car is black.

Either (1b) or (1c) could plausibly follow (1a). However, consider the sequence:

(2) a. Bill doesn't have a car. b. *It is black.

c. *The car is black.

Neither (2b) nor (2c) can follow (2a) because they presuppose the existence of a car that does not exist. When such existential presuppositions are violated comprehension takes longer (Haviland & Clark, 1974). Subjects read pairs of sentences like those below and pressed a button to indicate when they had understood the second sentence:

(3) a. We got some beer out of the trunk.

b. The beer was warm.

(4) a. Andrew was especially fond of beer.

b. The beer was warm.

The definite article in 3b and 4b presupposes the existence of some particular beer. Sentence 3a establishes the existence of some particular beer (namely the beer that was taken from the trunk), but 4a does not. As predicted, subjects had longer comprehension times for 4b and 3b. The difference in comprehension times demonstrates that the reader tries to relate the meaning of the second sentence to the representation established by the prior sentence.

Inappropriate anaphoric reference can also disrupt the comprehension of larger units of text, such as passages. Presenting the sentences of a passage in a scrambled order disrupts shadowing performance to a greater degree if the passage contains more anaphoric reference (Rosenberg & Lambert, 1974). In other words, the more closely the original sentences were related the more disruptive was the violation of the passage structure. The results show that even in a shadowing

task, people use anaphoric reference as a cue to comprehension; the violation of the passage structure makes the cue misleading.

Much like pronouns, definite articles encourage people to integrate sentences in comprehension and in memory. This integrative behavior was examined in a study in which subjects read a list of 17 sentences that could form a coherent passage (DeVilliers, 1974). However, the subjects were not told that the sentences could be related to each other. The sentences contained indefinite or definite articles. The following sentences are excerpted from the sequence of sentences with indefinite articles:

A man bought a dog.
A child wanted an animal.
A father drove to his house.
A cottage stood near a park.
A boy was delighted with a gift.
A twosome went exploring along
a path into a woods.

When the indefinite articles are replaced with definite articles, the same sequence of sentences seems to form a story.

A man bought a dog.
The child wanted the animal.
The father drove to his house.
The cottage stood near the park.
The boy was delighted with the gift.
The twosome went exploring along
the path into the woods.

In both conditions, the sentences were presented one at a time in a memory drum. About half of the subjects in the definite article condition reported that the sentences seemed to form a story. These subjects recalled more sentences and had more inter-sentence lexical substitutions (for example, substituting dog for animal in recalling the second sentence). By contrast, the subjects in the indefinite article condition did not think that the sentences formed a story. Their recall was poorer and they did not make co-referential substitution errors. The definite

articles increase the probability that readers will integrate the sentences, and when they do integrate them, then recall is improved.

Summary

We have reviewed a number of linguistic devices that can facilitate comprehension processes. Devices such as dovetailing, repetition of key words, and intersentential connectives set the discourse pointer so that the reader is prepared to integrate the next clause or sentence. This approach suggests that "good" writing may optimize the reader's comprehension processes. However, not all good literature is written to be optimally comprehensible. For example, stream-of-consciousness writing is not meant to facilitate comprehension, but rather to induce a sense of confusion. While our approach is not appropriate for all writing and comprehension tasks, it is applicable in the many cases where the primary goal is efficient communication of information.

At the beginning of this chapter, we argued that understanding what someone is talking about involves more than just deriving a representation of a sentence. Comprehension also involves relating the words and clauses in a sentence to other sources of information, such as the previous discourse or the perceptual context of the discourse. The various linguistic devices we have discussed provide cues to integrating a sentence with extra-sentential information. The integrative processes influence the speed with which we understand sentences in context and the accuracy with which we later remember them.

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[redacted] the author of authors is anonymous. This paper represents a collaborative effort. The project was supported in part by the National Institute of Education, Grant NIE-G-78-0058 and by the National Institute of Mental Health, Grant MH-07725, U.S. D. Department of Health, Education and Welfare.

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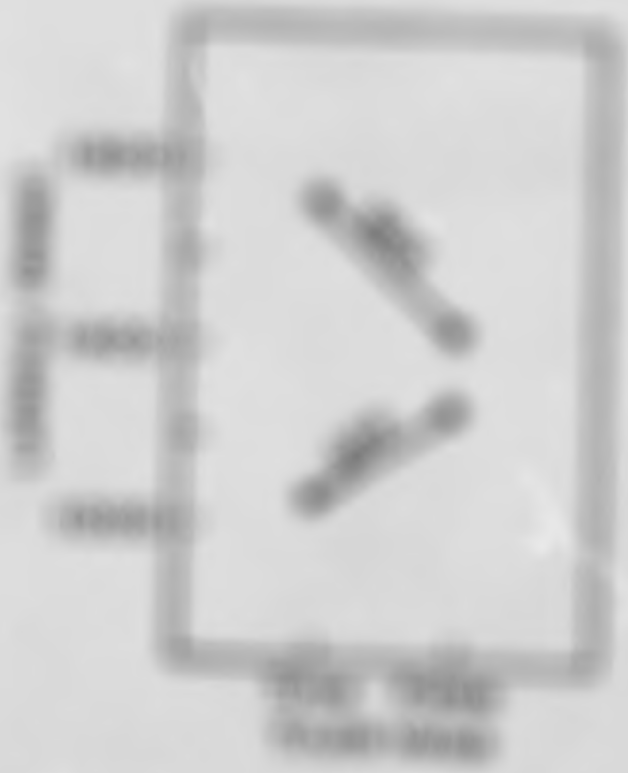


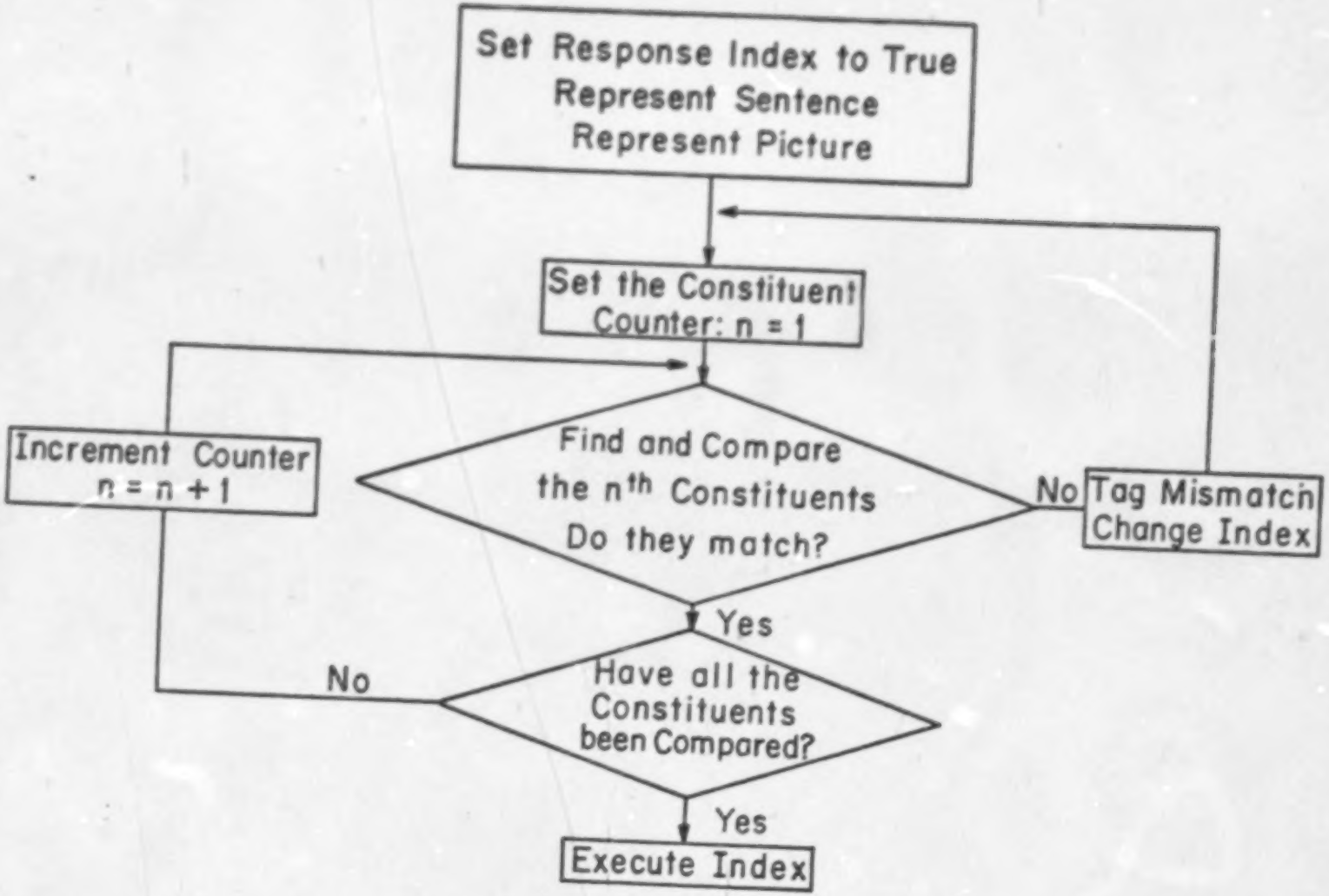


Figure 2. A model of the processes in verification.

comparing constituent by constituent starting with the inner proposition. The inner constituents match and since both the sentence and picture are affirmative, the polarities also match. Thus, there are no mismatches and no extra operations. Therefore, the time for a true affirmative represents the base time it takes to represent the sentence and picture and compare matching constituents.

When there is a mismatch, there are extra operations that increase the latency. A mismatch causes the comparison process to begin again with the inner constituents. For example, in the false affirmative case, the sentence says The dots are red but the picture shows black dots. The inner constituents mismatch and this has several consequences, that are detailed in Table 2. (A plus under two constituents denotes a match; a minus denotes a mismatch). The mismatch causes a change in the response index, from true to false. Also, the two constituents are tagged so they won't mismatch on future comparisons. Then, the inner constituents are recompared. And finally, the polarities are compared, and found to match. So this condition involves one more comparison operation than the true affirmative condition. A false negative has two more comparison operations than the true affirmative because of the mismatch between polarity markers. And a true negative has three extra comparisons because of mismatches between both the inner constituents and the polarity markers.

Insert Table 2 about here

Table 1 derives the predictions of this model for the four conditions. The model postulates a linear increase in the number of comparison operations, from true affirmatives to false affirmatives to false negatives

TABLE 2

A trace of the operations in verifying a false affirmative

	Stimulus sentence:	The dots are red.
	Stimulus picture:	A set of black dots
Operations		
Initialize response index to true		
Represent sentence:		(AFF, (RED, DOTS))
Represent picture:		(BLACK, DOTS)
1. Compare first constituents		-
Tag sentence constituent		(AFF, (M))
Tag picture constituent:		(M)
Change index to false		
Re-initialize comparison process		
2. Compare first constituents		+
3. Compare second constituents		+
Respond with content of index:		False
Number of comparisons:		k + 1, where k = 2

to true negatives. If the response latency is a direct function of the number of comparison operations, there should be a corresponding linear increase in latencies in the four conditions.

Insert Figure 3 about here

Figure 3 shows the exact same results as in Figure 1, but now plotted a different way. The X-axis represents the number of comparisons hypothesized for the four conditions. As predicted, the latencies show a linear increase. In fact, we have found this linearity in a large number of studies (summarized in Carpenter and Just, 1975). This supports the idea that there is an iterative "find and compare" operation and that mismatches cause re-initialization of the comparison process and consequently, extra operations.

This model can explain the processing of explicit negatives--sentences with the not morpheme. In the next set of experiments, we used this paradigm and theory to investigate how implicit syntactic negatives are processed. A syntactically negative phrase can be identified by using what linguists call "co-occurrence rules." An example of such a rule is that negative clauses can co-occur with either (Klima, 1964). For example, it's okay to say Mary didn't go and John didn't go, either; but you can't say Mary went and John went, either. Normally, you would say too, rather than either. Since, either only co-occurs with negatives, it signals the presence of a negative; it acts as a sort of litmus test. This co-occurrence rule suggests that words like few, hardly any and seldom are negative because phrases with these quantifiers can be "either-conjoined." For example, Hardly any boys went; hardly any girls went, either, is an acceptable sentence. There are other quantifiers

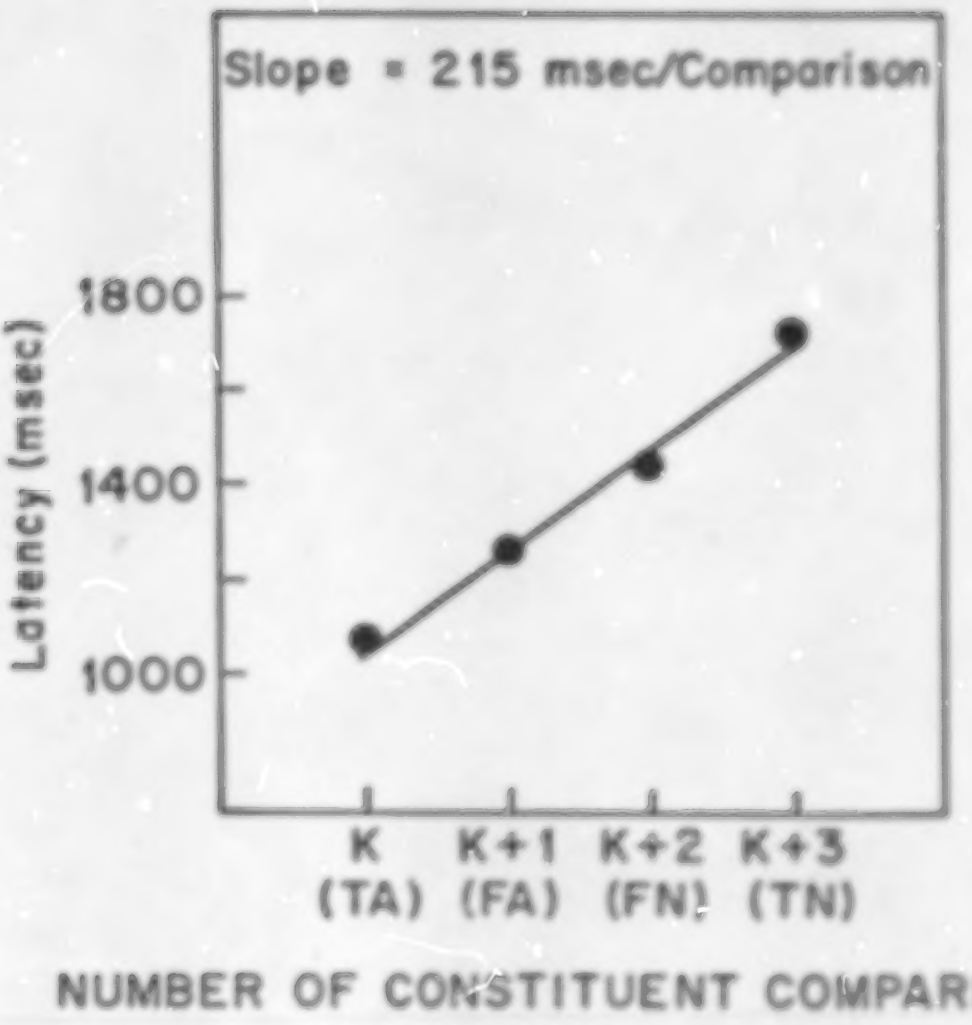


Figure 3. Results from the verification experiment plotted according to the hypothesized number of operations (data from Just and Carpenter, Expt II, 1971).

that can't be "either-conjoined." For example, it's not acceptable to say *A minority of the boys went and a minority of the girls went, either.*

The linguist has presented some interesting co-occurrence rules pointing out a contrast between words like *hardly any* and those like *a minority*. Now psychologists can ask what are the processing implications of this linguistic distinction? Can sentences with *hardly any* be processed differently from those with *a minority*? The verification paradigm and the model also go to determine how such sentences are internally represented and processed.

The experiment we ran to examine this question was a verification task where we presented our subjects with one of three kinds of quantified sentences. One kind of sentence had quantifiers like *few*, which the linguist would call syntactically negative. The psychological question is whether *few* is processed like a negative. A second kind of quantifier like *many* and *most*, was affirmative and referred to a large subset. Notice that according to the co-occurrence rule they are affirmative, since you can't say *Many of the boys went, many of the girls went, either.* The third type of quantifier refers to a small subset, like *a minority* or *a small proportion*. These are also affirmative by the linguistic co-occurrence rule; you can't say *A minority of the boys went and a minority of the girls went, either.* In the experiment (Just and Carpenter, 1971), the subject read a sentence like *Many of the dots are red.* The display showed a large subset of dots of one color and two exceptions. For example, the large subset could be fourteen red dots and the small subset would be two black dots, or vice versa. The predictions are

be derived by considering how the sentences are represented. The sentence *None of the dots are red* presents a set in extension) represented as an affirmative. As just like the *a* affirmative discussed before, the true zone should be easier if that the false zone. However, *Few of the dots are red* may be represented and processed like a negative. If it is, the false zone should be as easier than the true zone.

[illegible] and bias

The results in Figure 4 also show our hypothesis on sentences *only* is processed like an affirmative, while *few* is processed like a negative. The results for quantifiers like *few* can not be connected with the results for quantifiers like *a minority*. Sentences with quantifiers like *a minority* were easier when they were true, i. supporting our hypothesis that such quantifiers are represented as affirmatives about the smaller subset.

At this point, our findings provide a converging opening to further study the way these structures are represented and processed. In the first experiment, we investigated whether or the level of fixation would reflect on how these implicit negations are to represent. We saw in a visuomotor study we could monitor how the semantic fixated the private after reading the sentence (Carp Knot and Knot, in [illegible]). If *few* is internally represented as a negation of *many*, a mindset might subsequently fixate the larger subset. In contrast, if *a minority* is represented as an affirmative quantifier about the smaller subset, a subject should look at the smaller subset. By analogous reasoning, a sentence with *many* might cause the subject to look at the largest subset.

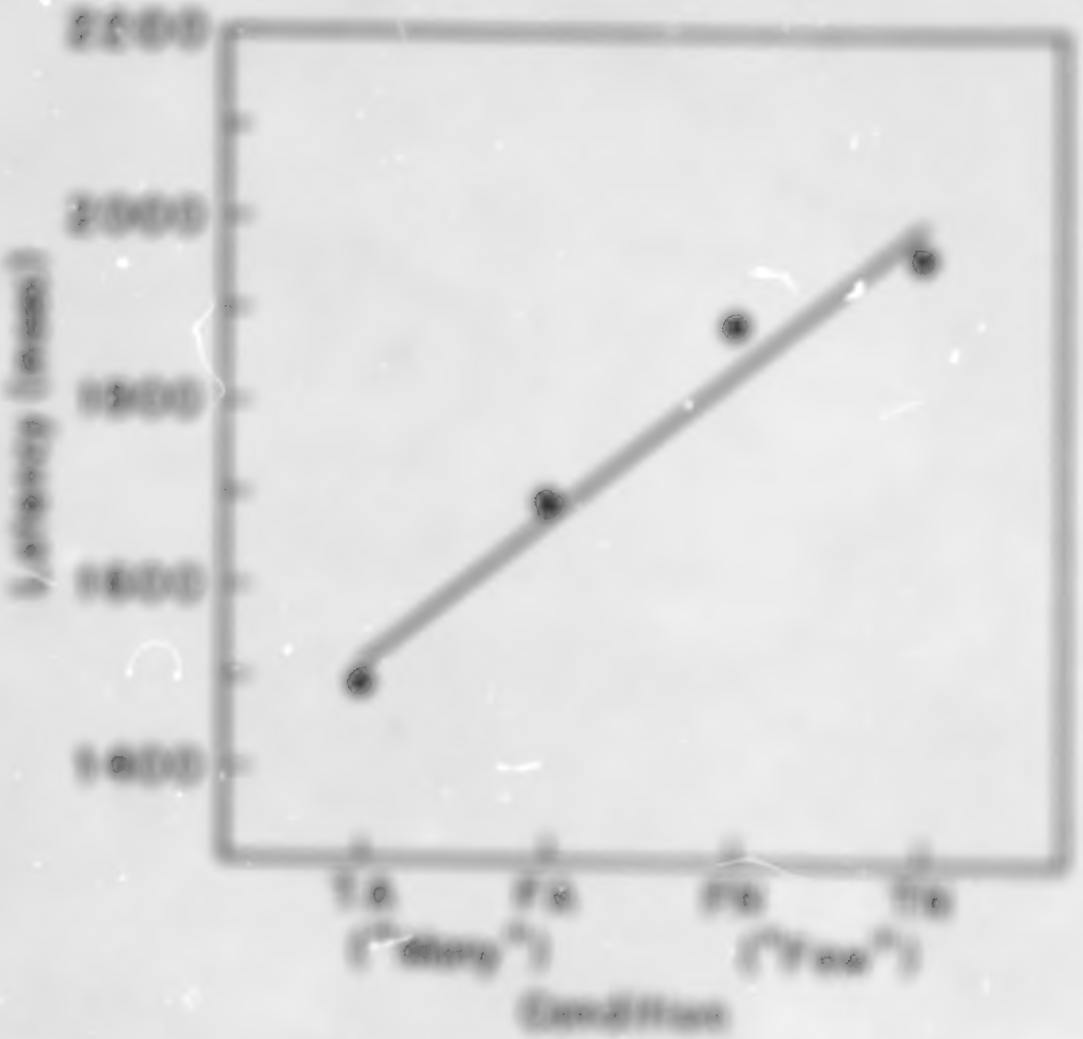
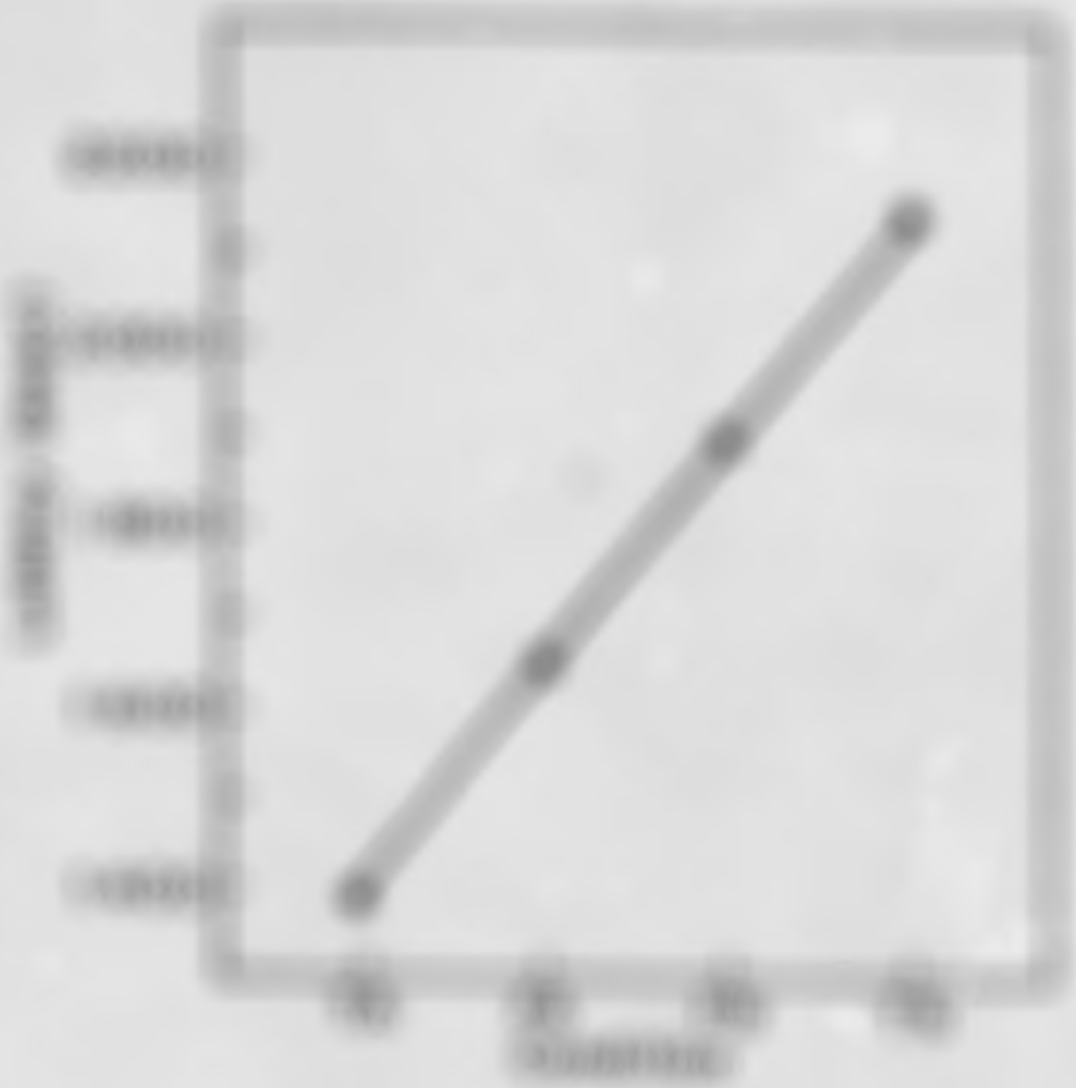


Figure 4. [illegible]



reflect the mental operations we have proposed in the model of verification--operations such as comparing predicates, comparing polarity markers, and doing extra comparisons after encountering a mismatch between the sentence and picture representations. To answer this question, we computed the average duration that a particular part of the display was fixated in a trial. (For purposes of scoring, the screen was divided into a three by three matrix. All fixations within one of the nine squares were considered equivalent.) In this way, we broke down the total latency into four components. The first component is the duration of the initial fixation on the sentence. This was also the first fixation in a trial. The second component measured the duration of any subsequent fixations on the sentence if there were intervening fixations on other locations. The third component measured how long a person fixated the location mentioned in the sentence. For example, if the sentence said Isn't East, this component measured how long the East square in the display was fixated. Finally, the fourth component measured the time spent in any location other than the sentence or the location mentioned in the sentence.

As Figure 7 shows, the amount of time a person fixated these various locations does reflect the proposed underlying operations. The duration of the first component, the initial fixation on the sentence, is influenced by whether or not there is a negation. The duration is significantly longer when the phrase is negative. The duration of subsequent fixations on the sentence is determined by whether or not there is a negative and whether or not there is a mismatch on the predicate. In other words, this duration is proportional to the

hypothesized number of comparison operations. The third component, the time spent on the location mentioned in the sentence, is determined by whether the sentence is affirmative or negative. Again, the duration is significantly longer when the sentence is negative. Finally, the duration of the fourth component, fixations on other locations, is determined by whether or not there is a plus in the location mentioned in the sentence. This duration is significantly longer when there is no plus in the location mentioned in the sentence, namely in the false affirmative and true negative conditions. Thus, all four components reflect the very orderly effects of mismatches between corresponding constituents of the sentence and picture representations.

Insert Figure 7 about here

These results demonstrate two very important points. First of all, the total latency fits the model's predictions. Moreover, each of the four component latencies reflect the kinds of processing stages postulated to underlie verification. It still remains to map the details of these results onto the model. However, the durations of the component latencies seem to reflect processes like comparing constituents. Thus, the duration of eye fixations, as well as the locus of fixations, as shown in the previous experiment, can be used to study comprehension.

What is exciting about this eye movement research is that it is predicated on the hypothesis that eye fixations can be an externalization of the immediate processor. Eye fixations can be used to study what is being attended, encoded, and how it is being operated upon in immediate memory. We have shown that in these tasks, both the locus and duration of fixations reflect mental operations like encoding and

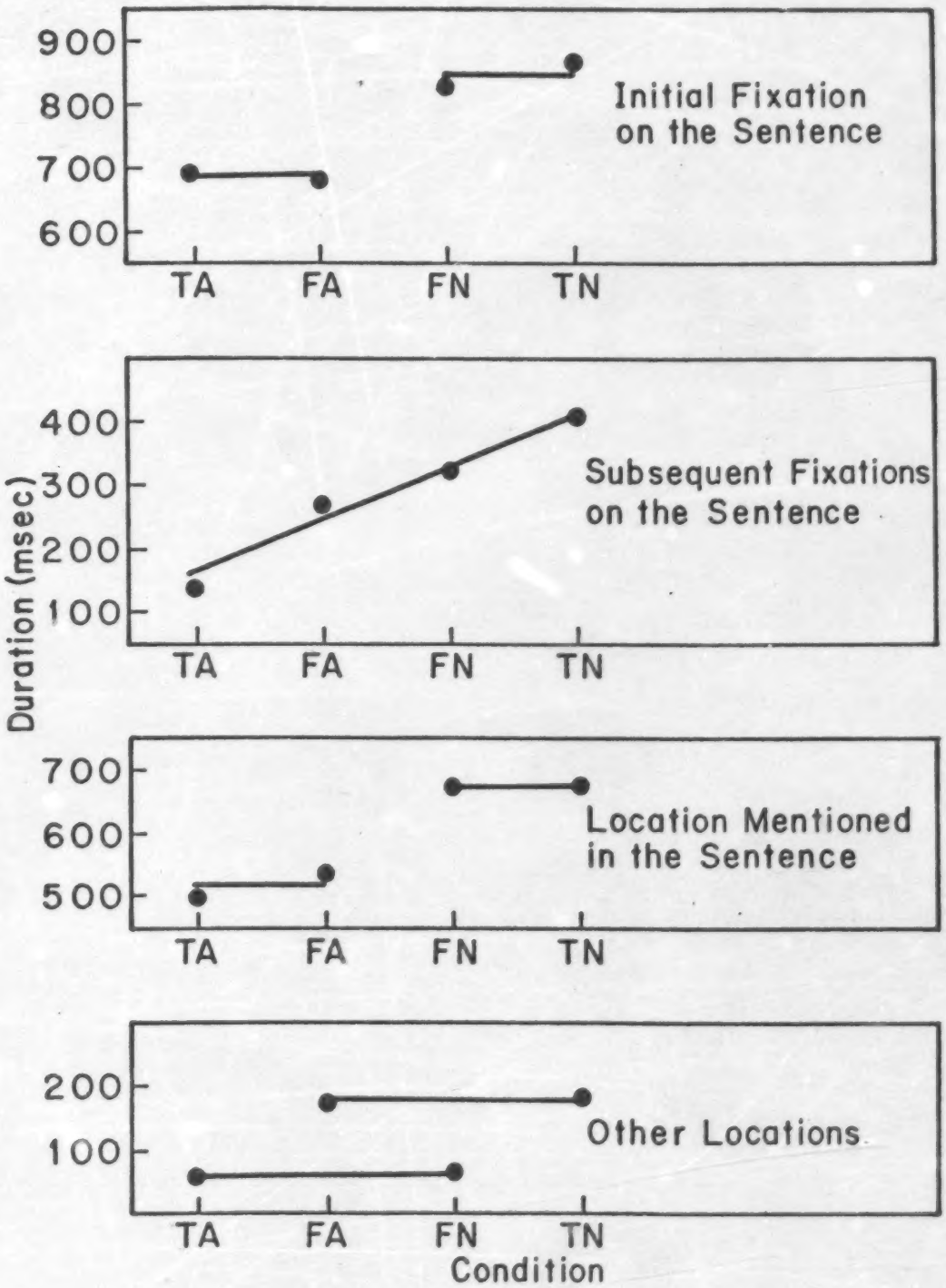


Figure 7. Duration of fixations on various parts of the display.

comparing representations. Thus, this represents a way of studying the extremely rapid mental operations in sentence comprehension.

The mental operations of encoding and comparing representations are not specific to tasks that involve visual scanning. In fact, the processing model presented above can explain sentence verification processes when the task requires that information be retrieved from semantic memory (Cf. Carpenter and Just, 1975; Just, 1974). For example, the model can predict the latencies to verify sentences like Seven isn't an even number or Eight is an odd number, which involve no visual scanning. The model is not concerned with whether the original source of information for a semantic structure is a visual display or previous knowledge of the world. While these will obviously entail somewhat different retrieval and encoding processes, it is the commonalities in processing that are of interest here. The model is concerned primarily with the general processes involved in representing and comparing abstract semantic structures. And the results suggest that this research, including conclusions from the eye fixation experiments, reflect many processes that are common to a variety of comprehension situations. Thus, this eye movement research may provide a way of studying general comprehension processes--not only those that involve visual search.

In summary, there are two main points. The first one is that the locus and duration of eye fixations are very systematically related to the underlying mental operations postulated for sentence verification. The second point is that we know how negatives are represented. A negative is represented as an affirmative core plus a negative tag. The difficulty of understanding negatives comes when that tag mismatches

some other source of information. Therefore, we now have the methodology and some of the answers. We can use this approach to investigate other interesting constructions, such as quantifiers, and comparatives. We are making real progress in finding out how people represent and process semantic structures.

DR. MONTY: I noticed you completely stayed away from any tendency to speak to the possibilities of subjects translating from words to mental images. Was this deliberate or were you speaking around it?

DR. CARPENTER: Mental images could be a possible format for certain kinds of processing. The difficulty is in understanding how someone would have a mental image that would correspond to a negative. And so that is why it is probably better to think of this task in terms of a comparison of abstract symbols. The other thing is that the abstract symbolic format suits cases where there may be no real images involved, for example when you're retrieving certain kinds of information from long-term memory: Nixon isn't a Democrat, true or false-- as fast as you can. I can predict the latency, and I am not sure that you generate images.

That doesn't preclude imaginal formats for other structures like comparatives and there is a current controversy about that.

DR. COOPER: Have you explored the possibility that whether a word like few is interpreted as a negative or a positive might depend upon surrounding verbal information? For example, if you consider the sentence, Although none of the dots in the group were red, few of the dots in group two were red.

DR. CARPENTER: Actually to make that sentence acceptable, you'd say ... A few of the boys in group two were sad. And, a few is an affirmative whereas few is a negative. If you test it with the co-occurrence criteria, this distinction is clear. You can say few of the boys went, and few of the girls went either, but a few of the boys went and a few of the girls went, either isn't acceptable.

DR. CHIPS: Isn't it just possible that depending upon the surrounding words of the critical word, few, few might either be interpreted as a negative or as a positive?

DR. CARPENTER: My theory is to think that there are cases where people convert negatives like few into affirmatives like a few or a minority. Certainly we do that with explicit negatives. So, we might take something like John isn't home and if we know there are only two alternatives we might internally convert it to John must be at school. And that conversion process, the conditions under which people do it, how long it takes, and what mental operations are involved in transforming sentences, is an interesting question. Whether context encourages such transformations is an empirical question.

DR. GRASS: One of the morals that generally the speakers this morning were making and that an awful lot of data suggested was that at least within the context of the reading ability, you could not predict where the next eye movement was going to occur, and the duration of the movements were relatively independent of virtually anything that was tested or manipulated.

Yet you are presenting data which is showing an incredible effect of the kind of mental operations that are being performed on these sen

But how long the eye lands. Sometime reading neglects to the extent of what you are discussing. There is that a consideration?

DR. KOLERS: I think the misrepresentation there is Anderson's data. Kennedy's data showed clearly that when a person makes an error that he spent a large amount of time on it.

DR. WOOD: But he did it by adding lots of fixations. You went to some length to suggest that the duration of these fixations was a relatively invariant phenomenon. But in challenging that in early sentences.

DR. CARPENTER: I want to be clear about how a thing and then I will answer your question. There data are the average duration/ spent at a location during a trial and the average duration of a single fixation.

But more to your point is that the decoding component of reading is kind of a minor component in this task. People in here what kind of semantic structures are possible. So when I am mentally tagging as I want to say are the kinds of operations that occur after initial decoding. I am using these operations as a subset as the people that represent information. But for communication are the processes in the original parsing process, this kind of approach has something to say about what kind of representation the parsing process must come up with.

You have to have parsing operations that determine the kind of structure that fits in with the results of these tasks. But I the representation of that parsing process is in that first box. It is a fascinating question. But, we are merely tapping another stage in the process. What do you do with information once you have represented it.

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